



**US Army Corps
of Engineers**

Tulsa District

TINKER AIR FORCE BASE

OKLAHOMA CITY, OKLAHOMA

INSTALLATION RESTORATION PROGRAM

SAFETY AND OCCUPATIONAL HEALTH PLAN FOR CORPS OF ENGINEERS PERSONNEL

REVISION 1, DECEMBER, 1988

ITEM 4

**TINKER AIR FORCE BASE
INSTALLATION RESTORATION PROGRAM**

**SAFETY AND OCCUPATIONAL HEALTH
PLAN FOR
CORPS OF ENGINEERS PERSONNEL**

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1. Individual Site Descriptions and Contaminant Summaries
2. Direct Reading Logs
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Health and Safety Plan for Corps of Engineers
Personnel at Tinker AFB IRP Sites

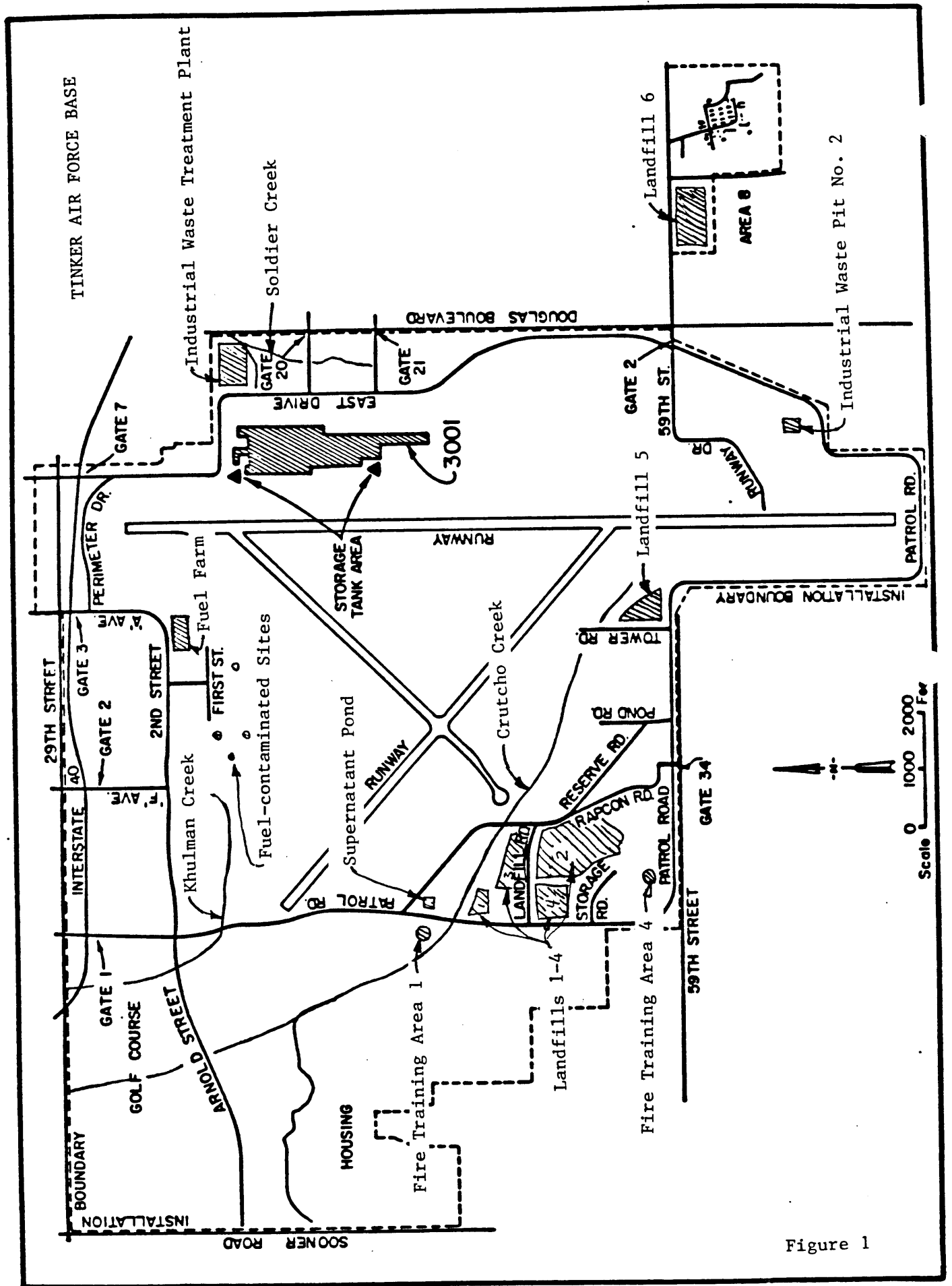
I. Purpose: This plan establishes procedures to protect Corps of Engineers' employees from potential safety and health hazards arising from investigation activities conducted in performance of the Installation Restoration Program (IRP) at Tinker Air Force Base. IRP investigations will be conducted at fourteen potentially contaminated sites. The individual sites are listed below and their locations are shown on Figure 1.

- A. Building 3001 and the surrounding area
- B. Industrial Waste Treatment Plant
- C. Fuel farm
- D. Landfills 1 - 4
- E. Landfill 5
- F. Landfill 6
- G. Fire Training Area # 1
- H. Fire Training Area # 4
- I. Soldier Creek
- J. Crutch Creek
- K. Khulman Creek
- L. Fuel contamination sites near Buildings 201 and 214
- M. Industrial Waste Pit # 2
- N. Supernatant Pond

II. Applicability: This plan applies to Corps of Engineers personnel, their contractors, and authorized visitors working in the identified areas. Supervisors are to ensure that employees understand and follow these guidelines.

III. References:

- A. COE Safety and Occupational Health Requirements Manual 385-1-1, October 1984.
- B. 29 CFR 1910 and 1926, OSHA Regulations.
- C. Tulsa District Respiratory Protection Program.



D. NIOSH/OSHA/USCG/EPA, Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, October 1985.

E. Environmental Protection Agency, "Guidance on Remedial Investigations under CERCLA", May 1985.

IV. Investigation Activities: IRP site investigations will include drilling, soil and groundwater sampling, surface water and stream sediment sampling, soil-gas surveys, geophysical surveys, and topographic surveys. Brief descriptions of several anticipated field investigation activities are given below:

A. Drilling: Drilling will be performed at some of the sites during the collection of soil samples and the installation of monitoring wells. Some of the boreholes will likely penetrate material that is known or suspected to contain hazardous waste.

B. Groundwater Sampling: This activity will involve the use of pumps, bailers, sample containers, chemicals, and various other types of equipment and supplies. Water samples representative of the groundwater beneath the sites will be obtained and preserved for analysis.

C. Surveying: Surveys will be performed during site investigations to locate boreholes, monitoring wells, site boundaries, etc.

D. Other Activities: Other techniques of investigation may include the performance of ground-penetrating radar surveys, soil gas analysis, surface soil sampling by hand methods, etc.

V. Hazard Evaluation: This section identifies potential hazards associated with the work operations described above. A brief site description and a summary of the contaminants previously encountered or anticipated to be encountered is provided in Attachment 1.

A. Drilling: It is anticipated that drilling and sampling activities have the potential for exposing employees to parts per million (ppm) levels of organic contaminants resulting from fuel spills, landfill leachate, and industrial waste and sewage sludge disposal. The primary exposure routes during drilling operations will be skin absorption and ingestion, and to a lesser extent, inhalation due to contaminant volatilization from the drill cuttings.

B. Groundwater Sampling: Groundwater sampling activities will have the potential for exposing employees to part per billion (ppb) levels of organic contaminants dissolved in groundwater. Again, the primary exposure routes will be skin absorption and ingestion, and to a lesser extent, inhalation due to contaminant volatilization from sampled water.

C. Surveying: Survey crews will have little if any potential for exposure to hazardous materials.

D. Other Activities: Personnel performing geophysical surveys, soil-gas analyses, and surface soil sampling will potentially be exposed to ppm levels of organic contaminants from fuel spills and disposed industrial waste. Primary

exposure routes will be skin absorption and ingestion, and to a lesser extent, inhalation due to contaminant volatilization from samples.

VI. General Safety and Worker Protection Requirements.

A. General.

1) Normal drilling and sample gathering procedures will be followed with two exceptions. The exceptions are air monitoring for combustible and non-combustible gases, and wearing special protective equipment and clothing as necessary.

2) The Safety and Occupational Health Office (S&OHO) will conduct periodic inspections to determine if modifications are needed in the safety and health procedures established for this work. The Industrial Hygienist (IH) will be on-call during the start-up operations, and on site if necessary during the project. The IH will determine what airborne and other sampling is necessary for protection of field personnel.

B. Worker Protection.

1) Emergency Station and Equipment: The on-site supervisor or lead employee shall place an emergency station upwind of the field operations. The emergency station shall be equipped with; eye and hand wash facilities including soap, towels and potable water; and a standard first aid kit.

2) Respirators: The respirators provided will be MSHA or NIOSH approved dual cartridge, air purifying respirators as selected by the I.H. The respirators will be worn as determined necessary by the I.H. The selection, use and care of the respirators will be in accordance with OSHA 1910.134 regulation and the Tulsa District Respiratory Protection Program. When not in use, the respirators will be kept at or near the emergency station.

3) Protective Clothing: No protective clothing is required to survey wells. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table.

4) Hand and Foot Protection: Chemically impervious gloves and safety toe boots will be worn to minimize bodily contact with hazardous materials. The I.H. will determine the type boots and gloves needed for protection against the potential exposures to chemicals known to exist in the waste sites. Employees must wash their hands before breaks, smoking, and lunch periods even though they are wearing protective gloves. Employees are encouraged to shower immediately after work.

5) No smoking is allowed on the potentially contaminated drilling sites, or wherever else prohibited by Tinker AFB regulations.

6) Hearing protection will be worn where noise is greater than 85dB (A), as directed by Safety Office.

7) Safety glasses, goggles or other eye protection are required where necessary as specified by Tinker AFB, Corps of Engineers or OSHA regulations.

C. Heat Stress: The use of protective equipment in particular respirators and tyvex clothing greatly increases the potential of heat stress. Where temperatures exceed 90 F, work procedures requiring respirators or clothing should be limited to early morning or late afternoon hours. Frequent breaks are mandatory. All employees should drink plenty of fluids. All (employees) for symptoms of heat stress.

1) The symptoms of heat cramps are; muscle cramps in legs and abdomen, pain with the cramps, faintness, and profuse perspiration.

2) The symptoms of heat exhaustion are; weak pulse, rapid and usually shallow breathing, generalized weakness, pale, clammy skin, profuse perspiration, dizziness, unconsciousness, and fainting.

3) The symptoms of heat stroke are; sudden onset, dry, hot, and flushed skin, dilated pupils, loss of consciousness, full and fast pulse, deep breathing at first to shallow breathing later, muscle twitching, convulsions, and high (105-106F) body temperature.

D. Air Monitoring: On-site monitoring will consist of a Photoionization Meter, Combustible Gas Meter (CGM), detector tubes, and air sampling pumps. Survey teams, drillers, geotech personnel, and supervisors will be instructed and trained in the use and limitations of the equipment. On-site monitoring\screening shall be conducted as required by the site monitoring plan. Generally, work activities inside contaminated sites such as drilling or hand borings, shall require daily monitoring throughout the work shift.

Attachment 2 contains a Direct Reading Instrument Form to be used in the field locations to record the sample readings. An example form has been prepared and included in the attachment. In general, drilling operations will require a breathing zone sample every 30 minutes or whenever new material or odors are encountered; augering and borings require a sample each time the auger or bore tube is removed; Groundwater samples require a measurement for each sample, if it is oily or odorous.

1) Photoionization Meter (HNU or TIP): The PM shall be used to determine the potential levels of ionizable vapors at the work site. Where contaminants are known i.e. TCE, the HNU equivalent units shall be converted to PPM for exposure evaluation. For unknown concentrations of ionizable compounds, readings greater than 10 HNU units in the employees breathing zone, the work shall stop and the Safety Office notified immediately. The S&OHO personnel will determine what follow-on actions are necessary. On-site personnel may decide to abandon the hole and proceed to the next to avoid delays or conflicts with work schedules, while waiting for instructions from the Safety Office, if this does not expose personnel to hazards while retrieving equipment.

2) Combustible Gas Meter (CGM): The CGM shall be used to determine the potential for a explosive atmospheres in the working area. For survey work the CGM shall be used to screen gases in and around barrels, and drums for explosive concentrations. Drill crews shall use the CGM while drilling to determine if potential explosive concentrations of gases in an area exist. Readings taken at the opening of a barrel or well are indicative of vapor-gas escape, but may be inaccurate or inconclusive. Readings taken approximately 1 foot above the source are a more reliable indicator of a hazardous condition developing. Readings 1 foot above a source showing continuous 25% of LEL or greater require immediate shut down. The Industrial Hygienist shall be notified immediately to determine further action.

A combination combustible gas/oxygen and/or hydrogen sulfide meter may also be available for use. The potential for an atmosphere deficient oxygen is unlikely for the work being conducted. However any confined space entry work shall require the use of an oxygen meter. No person will be allowed to enter or work in any area where the oxygen level is less than 19.5%.

Hydrogen sulfide generally will not be a potential problem, but the H₂S reading is useful to determine the presence of sulfides in the landfills. Reading greater than 10 ppm of H₂S above a source require immediate shut down. The Safety office shall be notified immediately to determine further action.

3) Detector Tubes: Air approximately 1 foot from the source shall be drawn through the tubes, as for CGM after gross screening is completed using the CGM, detectors tubes shall be utilized by the survey team to determine potential exposure concentrations to solvents and/or gases. Detectors tubes may be used to roughly identify solvents, but accuracy is extremely limited.

4) Air Sample Monitoring: Air monitoring for potential exposures is at the discretion of the Industrial Hygienist. Air monitoring may consist of area and personal sampling for potential contaminants. Air sample monitoring shall conform to standard I.H. procedures, and results will be obtained from a certified analytical laboratory.

E. Chemical Inventory: Attachment 3 contains information on the most common chemicals/compounds identified or suspected to be in the one as to be investigated. Where possible workers will be provided with Material Safety Sheets (MSDS) or other published information listing exposure limits, major routes of exposure and explosive limit values.

F. Training: All employees, supervisors, contractor personnel, and assigned personnel shall have a 40 hour Hazardous-Toxic Waste Training Course prior to work on sites identified as Hazardous-Toxic Waste sites, SuperFund, and DERA projects. At least one person in each work party shall have completed a basic First Aid training course in the last 3 years

VII. Site Specific Safety and Worker Protection Requirements: Descriptions of the individual sites are given below. In addition to the general safety and worker protection requirements given above, the site specific requirements given below will apply.

A. Building 3001

1) Site Description: The Building 3001 site includes the building complex (covering 50 acres), two adjacent underground storage tank areas, and the surrounding areas encompassed by the lateral extent of the contaminant plume. The site is located near the north boundary of the Base and covers an area of approximately 220 acres. The underground storage tank areas include one site immediately north of the Building and one site southwest of the building, immediately southwest of the Building 3108. The sites are referred to as the north and southwest tank areas.

2) Site Activity: Well monitoring and sampling of all wells, and renovating of older wells. If necessary, some drilling of new wells and surveying of those wells may be performed in the future.

3) Worker Protection: No protective clothing is required to survey wells. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or Shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at Building 3001 will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is required when surveying well locations.

B. Industrial Waste Treatment Plant

1) Site Description: The Industrial Waste Treatment Plant (IWTP) consists of the wastewater treatment facility northeast of the Building 3001. Wastewater from various industrial activities on the Base is treated here. The treatment processes include oil/water separation, flow equalization, metals reduction/precipitation by sulfide precipitation, biological treatment by activated sludge, oxidation/disinfection by chlorination, and pressure filtration. Average flow through the facility is .94 mgd. Groundwater immediately downgradient of the IWTP is contaminated with chlorinated organic

compounds (vinyl chloride, chlorobenzene and dichlorobenzene). Adjacent to the IWTP is the Sanitary Treatment Plant (STP), where sanitary sewage is treated.

2) Site Activity: Installation of new groundwater monitoring wells, surveying wells, and sampling of existing and new wells at the site.

3) Worker Protection: No protective clothing is required to survey wells. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at Building 3001 will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is required when surveying well locations.

C. Fuel Farm

1) Site Description: The Fuel Farm covers approximately 5 acres. The Fuel Farm was an underground fuel storage facility, and has been converted to an above-ground storage site. There is a subsurface fuel product plume consisting of approximately 10,000 gallons floating on top of perched groundwater at the site. The groundwater is contaminated with minor amounts of benzene, toluene, and xylenes. Approximately 1200 gallons of fuel had been removed from the site by August 1988.

2) Site Activity: Future activities at the site include installing/rehabilitating wells in the fuel farm, drilling one new monitoring well, surveying well location and sampling groundwater.

3) Worker Protection: No worker protection is required to survey well locations. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is

recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at Fuel Farm will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is required when surveying well locations.

D. Landfills 1 - 4.

1) Site Description:

a. Landfill 1: Landfill 1 covers approximately 1 acre and was used from 1942 to 1945. The trenches run east to west and vary from 10 to 25 feet deep. General refuse and dried sludge from the domestic waste treatment plant were disposed of in this landfill.

b. Landfill 2: Landfill 2 covers approximately 20 acres and was used from 1945 to 1952. Trenches are approximately 20 feet deep and are excavated into sandstone. General refuse and small quantities of solvents and paints were disposed of here. This landfill contains Radiological Waste Disposal Site 1030W, a pit where rags and acetone solution which contained radium were burned. A pond was located on top of Landfill 2.

c. Landfill 3: Landfill 3 covers approximately 8 acres. Trenches are approximately 25 feet deep and are excavated into sandstone. General refuse, paint buckets, insecticide cans, and empty barrels were disposed of here.

d. Landfill 4: Landfill 4 covers approximately 16 acres and was used from 1961 to 1968. General refuse, and small quantities of solvents, paint, and insecticide were disposed of at this site. Trenches were 15 feet deep and excavated into sandstone. High concentrations of chemical oxygen demanding liquids, heavy metals, and phenols are present in leachate, which comes from the landfill during periods of wet weather.

2) Site Activity: Work to be performed includes sampling existing wells and possibly drilling and surveying in new wells.

3) Worker Protection: No worker protection is required to survey well locations. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling

operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at Landfills 1-4 will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is necessary when surveying well locations. Drilling activities on Landfill 2 near the Radiologic (Waste Disposal Site, 1030W, 1022E, and 62598 shall require Safety Office participation to determine proper screening measures and protective equipment. Cooperation with the Tinker AFB Safety Office in determining the degree of hazard shall also be required. All drilling at this location shall require the industrial hygienist on site.

E. Landfill 5

1) Site Description: Landfill 5 was in operation from 1968 to 1970. Waste disposed of consisted of general refuse with small quantities of industrial wastes. The trenches at the site run from northwest to southeast and are estimated to be 400 feet long, 50 feet wide, and 16 feet deep. Landfill 5 covers an estimated 6 acres and approximately 75,000 cubic yards of waste. After the landfill was closed, it was covered with soil and vegetated.

2) Site Activities: Work to be performed includes sampling existing wells and possibly drilling and surveying new wells.

3) Worker Protection: No worker protection is required to survey well locations. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at Building 3001 will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures

1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is required while surveying well locations.

F. Landfill 6

1) Site Description: Landfill 6 covers approximately 20 acres and was in use from 1970 to 1979. It is about 1/2 mile east of Tinker Air Force Base on land leased from Oklahoma City. General refuse, small amounts of industrial waste and industrial wastewater treatment plant sludge were disposed of at the landfill.

2) Site Activities: Work to be performed includes surveying well tops, sampling existing wells and drilling new wells.

3) Worker Protection: No worker protection is required to survey well locations and elevations. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at Landfill 6 will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

The drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples.

Surveying well tops does not require monitoring.

G. Fire Training Area # 1

1) Site Description: This site is an unlined diked area where fuel oil was burned. It was used from 1950 to 1962.

2) Site Activities: Work to be performed includes well sampling, drilling new borings, and surveying well and borings.

3) Worker Protection: No worker protection is required for surveying. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities at FTA-2 will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is required for surveying wells or borings.

H. Fire Training Area # 4

1) Site Description: FTA #4 is located southeast of the ammunition depot near the north edge of pistol pond. This site is presently a grassy area with no visible signs of its past use as a fire training area. Exact location or period of operation is presently unknown.

2) Site Activities: Work to be performed includes soil and water sampling, and surveying boring locations.

3) Worker Protection: No worker protection is required for surveying. Water samplers will wear as a minimum chemical resistant, vinyl, or latex rubber gloves. Drillers, helpers and inspectors will during drilling operations wear as a minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby work gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise

levels are greater than 85dB (A). Worker protection for other types of activities at FTA-4 will be established on a case by case basis survey wells.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole(s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples. No air monitoring is required for surveying wells or borings.

I. Soldier Creek

1) Site Description: Soldier Creek consists of two arms. The main streambed, East Soldier Creek, begins on the southeastern portion of the base as a storm drain which collects runoff from roadways, parking areas, and buildings. West Soldier Creek begins as a man-made channel built to collect runoff from the runway system. Soldier Creek received industrial waste discharges from the Building 3001 complex.

2) Site Activities: Work to be performed includes collection of sediment and surface water samples, groundwater monitoring well installation, surveying, and groundwater sampling.

3) Worker Protection: No protective clothing is required for surveying. Surface water and sediment samplers will wear as a minimum butyl rubber boots and chemical resistant, vinyl or latex rubber gloves. Soil and ground water samplers will wear as a minimum chemical resistant, vinyl or latex rubber gloves. Drillers helpers and inspectors during drilling operation which includes hand borings, will wear as a minimum hand toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities along the creek will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole (s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples.

Surveying and collection of sediment and surface water samples do not require monitoring.

J. Crutcho Creek

1) Site Description: Crutcho Creek runs north and northwest through the eastern half of Tinker Air Force Base.

2) Site Activities: Work to be performed includes stream water and sediment sampling, well installation, surveying, and groundwater sampling.

3) Worker Protection: No protective clothing is required for surveying. Surface water and sediment samplers will wear as a minimum butyl rubber boots and chemical resistant, vinyl or latex rubber gloves. Soil and ground water samplers will wear as a minimum chemical resistant, vinyl or latex rubber gloves. Drillers helpers and inspectors during drilling operation which includes hand borings, will wear as a minimum hand toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities along the creek will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole (s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples.

Surveying and collection of sediment and surface water samples do not require monitoring.

K. Khulman Creek

1) Site Description: Khulman Creek runs north and west through the north-central part of Tinker AFB.

2) Site Activities: Work to be performed includes stream water and sediment sampling, well installation, surveying, and groundwater sampling.

3) Worker Protection: No protective clothing is required for surveying. Surface water and sediment samplers will wear as a minimum butyl rubber boots and chemical resistant, vinyl or latex rubber gloves. Soil and ground water samplers will wear as a minimum chemical resistant, vinyl or latex rubber gloves. Drillers helpers and inspectors during drilling operation which includes hand borings, will wear as a minimum hand toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or Shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities along the creek will be established on a case by case basis.

4) Site Monitoring: Drilling activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole (s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples.

L. Fuel Contamination sites near Buildings 201 and 214

1) Site Description: Buildings 201 and 214.

a. Building 201: Three separate areas are affected around the building. Area BB on the west has an abandoned diesel tank and minor amounts of hydrocarbon contamination in the soil. Area BR has an abandoned tank of unknown contents and has both hydrocarbon and halocarbon contamination. Area BC has minor amounts of halocarbon contamination and is the site of an abandoned waste solvent tank.

b. Building 214: The area west of the south end of building 214 is the site of an abandoned tank of unknown contents. Various solvents were detected in the groundwater sample.

2) Site Activities: Work to be performed includes backhoe excavation to the tops of the tanks, soil and gas surveys, installation of several shallow piezometers, borings, and surveying.

3) Worker Protection: No protective clothing is required for surveying, soil-gas surveys, or operation of backhoe. Soil and groundwater samplers will wear as a minimum chemical resistant, vinyl or latex rubber gloves.

Drillers, helpers and inspectors will wear as minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby gloves during all drilling operations including hand borings. For oily waters and soils, replace the vinyl gloves with North Silver Shield gloves under the cotton knobby gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85dB (A). Worker protection for other types of activities will be established on a case by case basis.

4) Site Monitoring: Drilling and excavation activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole (s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Excavation activities inside the contaminated sites will require that all excavation are checked for combustible gases and ionizable compounds continually when workers are in the excavation.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples.

Surveying and collection of soil-gas samples do not require monitoring.

M. Industrial Waste Pit No. 2

1) Site Description: In 1958, Industrial Waste Pit No. 2 was constructed on a hill between Patrol Road and the Airfield runway. The pit received hazardous wastes such as waste oils, cyanides, chromates, phenols, solvents, and waste acids and alkalies (plate shop waste). The exact location of the pit is unknown. The pit was filled and graded in 1965.

2) Site Activities: Work to be performed includes borings through the waste pit, installation and sampling of wells in the vicinity of the waste pit, and surveying.

3) Worker Protection: No protective clothing is required for surveying, soil-gas surveys, or operation of backhoe. Soil and groundwater samplers will wear as a minimum chemical resistant, vinyl or latex rubber gloves. Drillers, helpers and inspectors will wear as minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby gloves during all drilling operations including hand borings. For oily waters and soils, replace the vinyl gloves with North Silver Shield gloves under the cotton knobby gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection

will be used where noise levels are greater than 85 dB (A). Worker protection for other types of activities will be established on a case by case basis.

4) Site Monitoring: Drilling and excavation activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole (s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water samples.

Surveying and collection of soil-gas samples do not require monitoring.

N. Supernatant Pond

1) Site Description: The Supernatant pond is located on Tinker AFB 75 feet east of Patrol Road and approximately 200 feet north of Crutch Creek. This site was possibly used until 1984 as an evaporation pond for industrial operations at the building on the west side of Patrol Road that houses the current 0² facilities.

2) Site Activities: Work to be performed includes soil-gas surveys, installation of several monitoring wells, borings, and soil and groundwater sampling, and surveying.

3) Worker Protection: No protective clothing is required for surveying, soil-gas surveys, or operation of backhoe. Soil and groundwater samplers will wear as a minimum chemical resistant, vinyl or latex rubber gloves. Drillers, helpers and inspectors will wear as minimum hard toe butyl rubber boots and vinyl or latex rubber gloves under their cotton knobby gloves during all drilling operations including hand borings. For oily waters and soils, replace the vinyl gloves with North Silver Shield gloves under the cotton knobby gloves. Protective disposable coveralls will be worn during all drilling operations except when augers or Shelby tubes are being used above the water table. Eye protection is recommended during all drilling operations. Hearing protection will be used where noise levels are greater than 85 dB (A). Worker protection for other types of activities will be established on a case by case basis.

4) Site Monitoring: Drilling and excavation activities inside contaminated sites will require the use of a combustible gas meter to monitor for explosive mixtures 1 foot above the borehole (s). Readings will be taken in the workers breathing zone as a minimum every 30 minutes while drilling.

Drilling activities shall also require that a photoionization meter be used to determine potential ionizable compounds in the breathing zone of the employees. Readings shall be taken at least every 30 minutes while drilling.

Well monitoring and sampling will require the use of a combustible gas meter and photoionization meter in the event that samples are oily or odorous in nature. Readings shall be taken at least once for each of those oily or odorous water sampling.

Surveying and collection of soil-gas samples do not require monitoring.

VIII. Physicals:

The COE provides core drill employees working on these projects an annual in-depth physical examination, including blood chemistry with complete blood count and differential; urinalysis; medical history; required chest X-rays; audiogram; pulmonary function testing; physician's interpretation for the employee's ability to wear a respirator. As required, the examination may include testing for heavy metals, i.e., lead, arsenic, mercury, PCB's and pesticides such as DDT, DDD, DDE.

IX. Safety Meetings:

a. The initial meeting will be given by personnel from the S&OHO. The subjects covered will include a summary of the history of the work sites and the potential hazards that may be encountered such as corrosive leachate and gaseous conditions while drilling. During the initial meeting, employees will be instructed in wearing air-purifying respirators, and use of the emergency/escape breathing apparatus. Each employee will have the respirator qualitatively fit-tested at this time. Employees will also receive instruction in the use of the explosive gas meter and the radiation detection meter, photoionization meter and detector tubes.

b. Additional safety meetings will be held as required throughout the life of the project.

X. Decontamination. Since all work will be conducted in level C protection, the decontamination procedures necessary for personnel will be (1) cleaning and storage of reuseable items such as boots and equipment, (2) disposal of the tyvek suits, gloves and other expendables at the end of each day. All items will be bagged for disposal. Equipment decontamination procedures are given in the Drilling, Sampling, and Analysis QA/QC Plan.

XI. Emergency Information.

Local Resources

Ambulance. At Base medical facilities.

Hospital Emergency Room. Base medical facilities.

Poison Control Center. Base medical facilities.

Fire Department. 734-3997 or 734-7964

Contact. Warren Roberts

Site Resources

Water Supply. On-Site

Telephone. COE office, 739-3930

Radio. On-Site

Other. Two way radios

Emergency Contacts

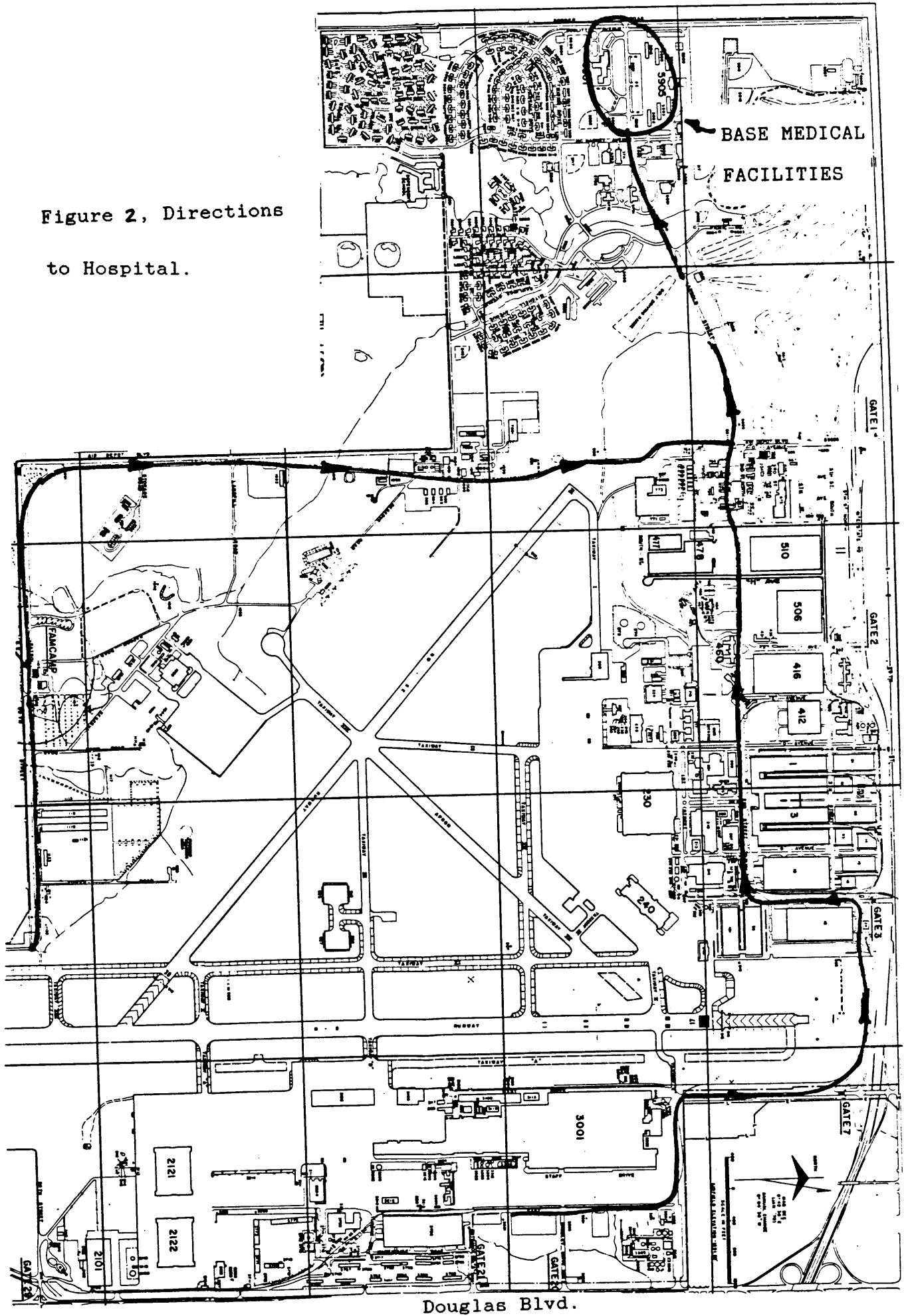
Bob Vandegriff Office: 918-581-7316 Home: 918-272-9238

Emergency Routes

Directions to Hospital. See Figure 2.

Other. Base medical facilities will be notified of on-site chemicals to assure that they are capable of treating exposed personnel.

Figure 2, Directions
to Hospital.



Douglas Blvd.

ATTACHMENT 1

INDIVIDUAL SITE DESCRIPTIONS
AND CONTAMINANT SUMMARIES

A. Building 3001

Site Descriptions: The Building 3001 site (as referred to in this report) includes the building complex (covering 50 acres), two adjacent underground storage tanks areas, and the surrounding areas encompassed by the lateral extent of the contaminant plume. The site is located near the northeast boundary of the Base and covers an area of approximately 220 acres. The underground storage tank areas include one site immediately north of the building and one site southwest of the building, immediately southwest of Building 3108. This report refers to these sites as the north and southwest tank areas.

Contaminant Summary: An excerpt from the Building 3001 RI Report is reprinted on the following pages which describes the groundwater and soil contamination at the site.

8.3 Groundwater Quality.

a. Background. Background groundwater quality has been determined by sampling wells which are upgradient of Tinker AFB. These samples were taken from perimeter wells installed for the Base-wide groundwater assessment (ref. 20), Building 3001 wells on the upgradient side of the site, and Base water supply wells. Average background values have been calculated for the producing zone, top of regional zone and perched zone and are shown in Table 8.10. These values do not necessarily represent uncontaminated groundwater, but represent the groundwater quality thought to be uncontaminated by operations associated with Building 3001.

Table 8.10
Background Averages of Groundwater Quality¹

	<u>Producing Zone</u>	<u>Regional Aquifer</u>	<u>Perched WT</u>
arsenic	0.002	0.002	0.010
barium	<0.500	0.663	1.11
cadmium	<0.0075	<0.0075	0.010
chromium	<0.010	<0.010	0.046
lead	0.033	0.048	0.057
mercury	<0.0004	<0.0004	<0.0004
selenium	0.0021	0.0005	0.0021
silver	<0.010	<0.010	0.010
nickel	0.019	0.033	0.101
zinc	0.44	0.12	0.11
chloride	4.9	42.1	297.4
sulfate	5.8	21.0	82.8
conductivity (umhos/cm)	442	718	684
pH (S.U)	7.17	9.80	7.10
TOC	2.2	5.3	3.9
oil and grease	<1.0	<1.0	<1.0
cyanide	<0.20	<0.20	<0.20
alpha (pc/l)	4.2	3.7	55.2
beta (pc/l)	9.0	9.3	106.8

¹ Concentrations in mg/l unless otherwise noted.

b. Contaminants in Groundwater. The chemical character of the groundwater in the vicinity of Building 3001 has been defined horizontally and vertically by laboratory analyses of samples from the monitoring wells at the site. The maximum contamination spread extends laterally beyond the limits of the building to the west approximately 1,750 feet, to the east approximately 1,100 feet, and to the southwest approximately 800 feet. The vertical extent of contamination is primarily in the upper 175 feet.

1) Perched Aquifer. Samples from the perched zone were from the monitoring wells listed in Table 8.1. The results of chemical analyses (Appendix G) indicated the zone is contaminated with organic solvents, trace metals, and fuel product. The highest areas of contamination are located beneath the building, the north tank area, and the southwest tank area. The compounds and metals detected in the perched zone are listed in Table 8.11. Two contaminants, TCE and Cr, can be considered the primary contaminants in the aquifer, because their maximum concentrations are higher than other contaminants and they are consistently detected over a larger area of the site. All other contaminants lie within the plumes of these two contaminants. Other organic compounds with significant plumes are 1,2-DCE, PCE, acetone, toluene, benzene, and xylene. Other metals with significant plumes are Pb, Ni, and Ba. A fuel product plume is present at the north tank area.

Table 8.11
Contaminants Detected in Perched Zone

Organic Compounds	Detected¹ Frequency	Concentration Range (ug/l)	Average² Conc (ug/l)	Max. Conc. Location
TCE	19/33	<5 - 330,000	12,125	34A
Toluene	10/39	<5 - 47,000	662	M-6
1,2-DCE	10/33	<5 - 4,600	376	1-12B
Acetone	11/33	<5 - 1,600	324	1-18
Benzene	10/39	<5 - 1,535	122	M-6
Xylene	6/39	<5 - 780	98	1-30
PCE	6/33	<5 - 260	102	35A
Total Metals	Detected Frequency	Concentration Range (mg/l)	Average Conc (mg/l)	Max. Conc. Location
Cr	27/33	<0.01 - 80	2.60	34A
Zn	33/33	<0.01 - 1.30	2.10	1-30
Ba	29/33	<0.05 - 28	3.6	1-18
Ni	33/33	13 - 1.10	0.2	1-30
Pb	33/33	< .01 - .57	0.10	1-30
Cd	9/33	<.005 - .020	0.006	1-30

1 Detected Frequency = Number of chemical detections/number of samples analyzed for parameter.

2 Average Values were calculated assuming concentrations below detection limits are equal to half of detection limit.

3 Fuel product was also present in the north tank area (well 1-30).

Table 8.12 lists the significant contaminants, the plume locations, approximate plume areas, approximate quantities of contaminants in the plumes, and the respective drawing number of each plume.

Table 8.12
Significant Contaminant Plumes in Perched Aquifer

Contaminant	Plume Location	Plume Area (acres)	Contaminant Quantity	Drawing
TCE	Entire Site	137	500 gal	10
1,2-DCE	Entire Site	78	138 gal	11
PCE	Entire Site	17	<1 gal	12
Toluene	N. and SW tank areas	5	20 gal	13
Benzene	N. and SW tank areas	9	2 gal	14
Xylene	N. and SW tank areas	3	<1 gal	15
Acetone	Entire Site	73	28 gal	16
Cr	Entire Site	221	825 lb	17
Pb	Entire Site	203	180 lb	18
Ba	Entire Site	176	7700 lb	19
Ni	Entire Site	96	220 lb	20

TCE concentrations ranged from 330,000 ug/l beneath the building (in well 34A) to less than 5 ug/l at the limits of the plume. The plume shape (drawing 10) indicates that the source was primarily beneath the building and migration is away from the building in the east, west, and southwest directions. This is the characteristic directions of the groundwater flow in this zone. Considerable quantities of 1,2-DCE are also present at the site. The plume has a similar shape (drawing 11) to the TCE with the highest concentrations detected beneath the building and west of the building. There are no records of 1,2-DCE being used at the building and some literature suggests that the compound is a result of anaerobic biotransformation of the TCE (ref. 1). PCE is also present primarily beneath the building with the highest concentration of 260 ug/l present at well 35A. Plume movement appears to be towards the east in the direction of East Soldier Creek. Total concentrations of Cr were detected throughout the site with the highest concentration detected at well 34A. The Cr plume has a similar shape to the TCE with movement away from the building in the east, west, and south directions. Pb is present with concentrations above the primary drinking water standard (.05 mg/l) and background concentrations (.057 mg/l). The plume (drawing 19) is concentrated primarily beneath the building with an apparent movement toward the southwest. Ba exists with a wide spread of concentrations above the primary drinking water standard (1.0 mg/l) and the background levels (1.11 mg/l). Cr, Pb, TCE, and 1,2-DCE contained elevated concentrations in the north fuel area. Also significant concentrations of nickel (Ni) and cadmium (Cd) are present in this area (wells 1-30 and 1-31). These metals and compounds are present due to migrations from operations within the building. As shown on the drawings, a storm drain line extends from the building, through this area, and discharges to West Soldier Creek. Therefore, it appears contaminants have migrated into storm drains in the building and leaked to the groundwater in this area.

a) Southwest Tank Area. Toluene, benzene, and xylene were found in high concentrations at the southwest tank area. Toluene ranged from 47,000 ug/l (well M-1) to less than 5 ug/l (well 1-16) during the sampling period. The plume is moving towards the southwest, which is the direction of groundwater flow in this area. Benzene ranged from 1535 ug/l (well M-6) to 15 ug/l in a similar shaped plume. Total xylenes concentrations ranged from 130 to 5 ug/l. Figures 8-2, 8-3 and 8-4 show this tank area in greater detail with the plumes of toluene, benzene, and xylene, respectively. The organics are the result of fuel leaks. As shown by the figures, the plume shapes indicate that the source is in the vicinity of the 7 abandoned fuel tanks (tank numbers 3140 - 3144, and 3146-3147). The plumes of toluene and benzene extend to the west beyond wells 1-16 and 1-17. An additional well cluster will be installed in the location shown (well 1-45 on drawing 1) to further define the extent of this contaminant spread.

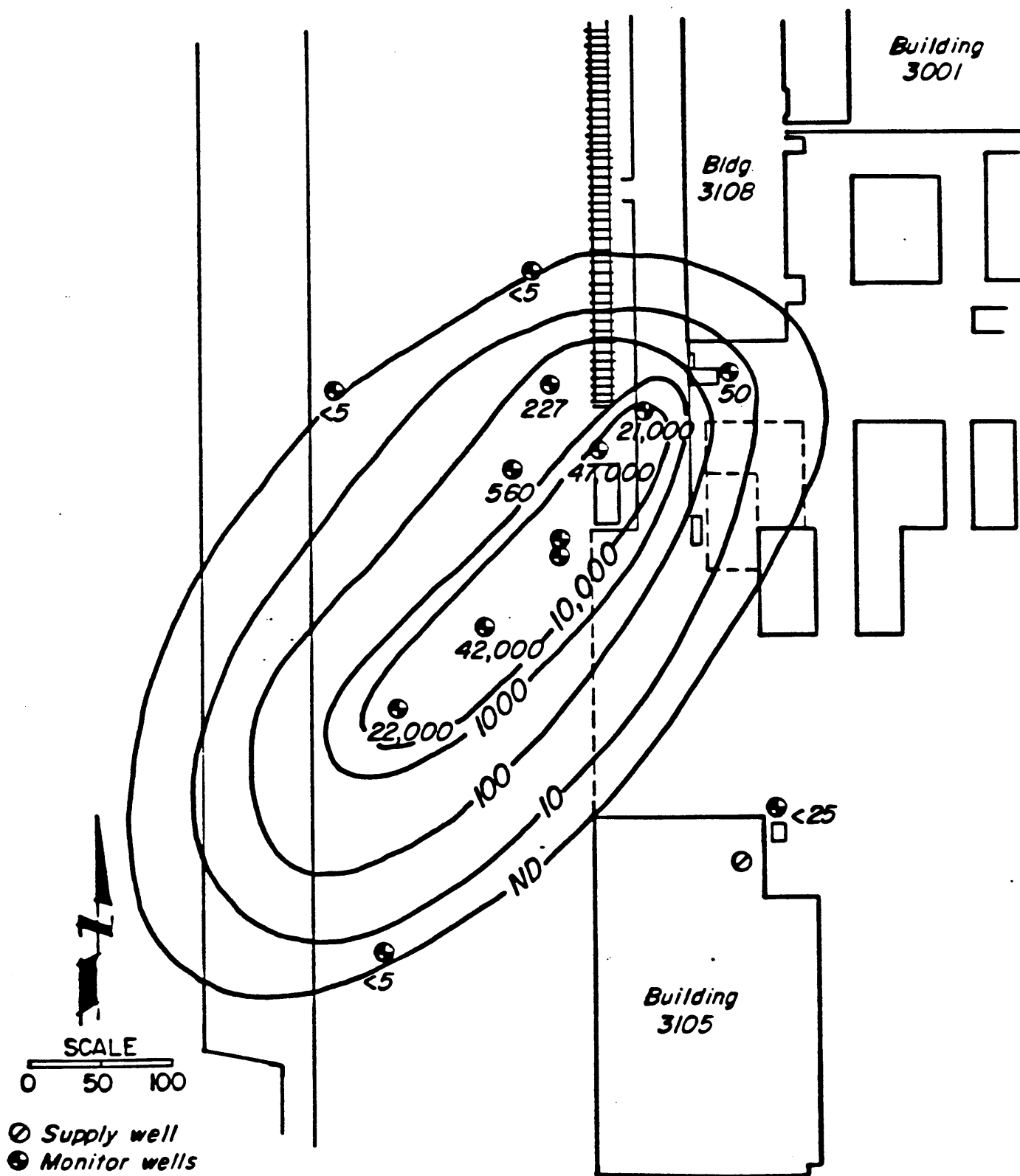
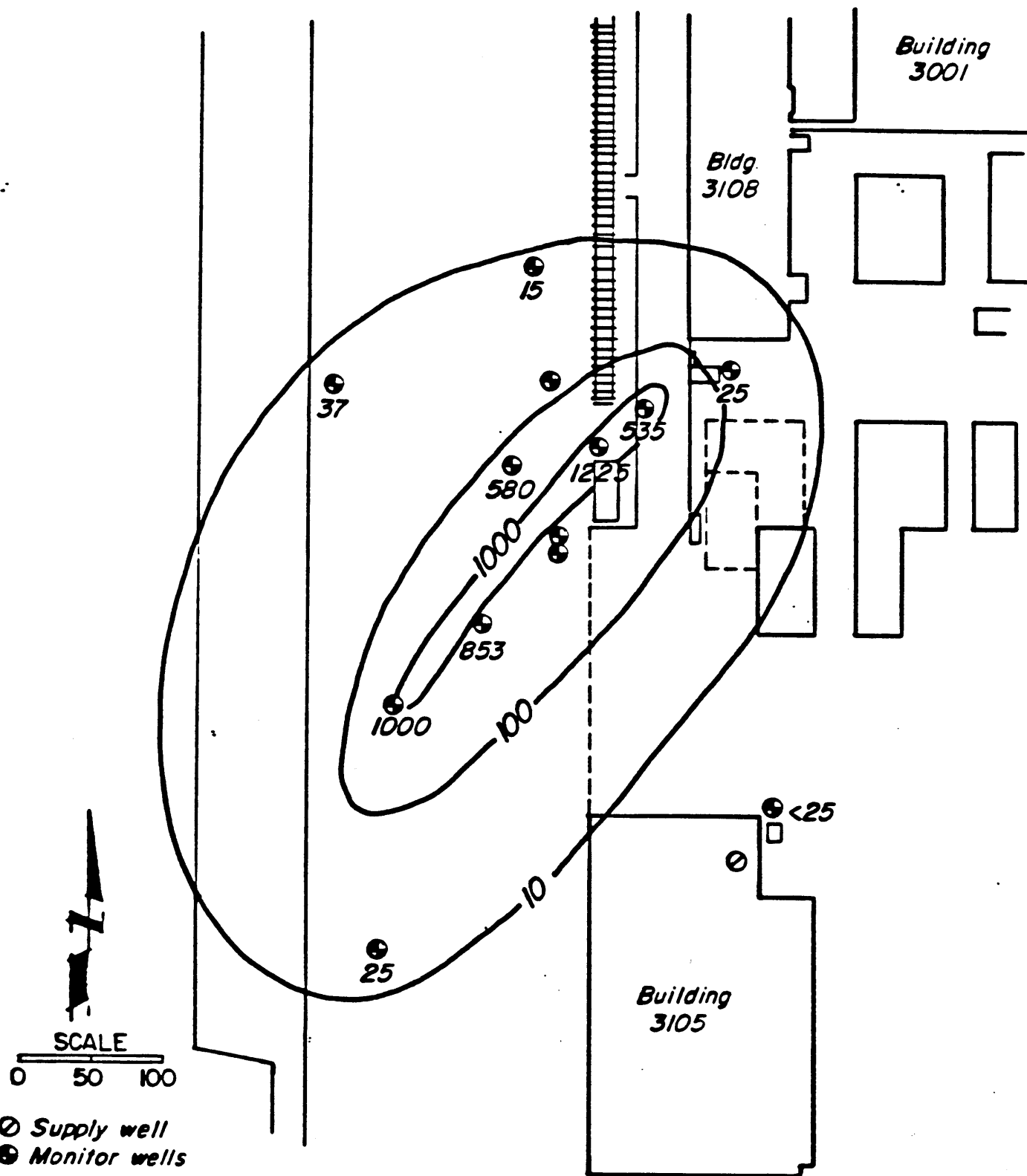
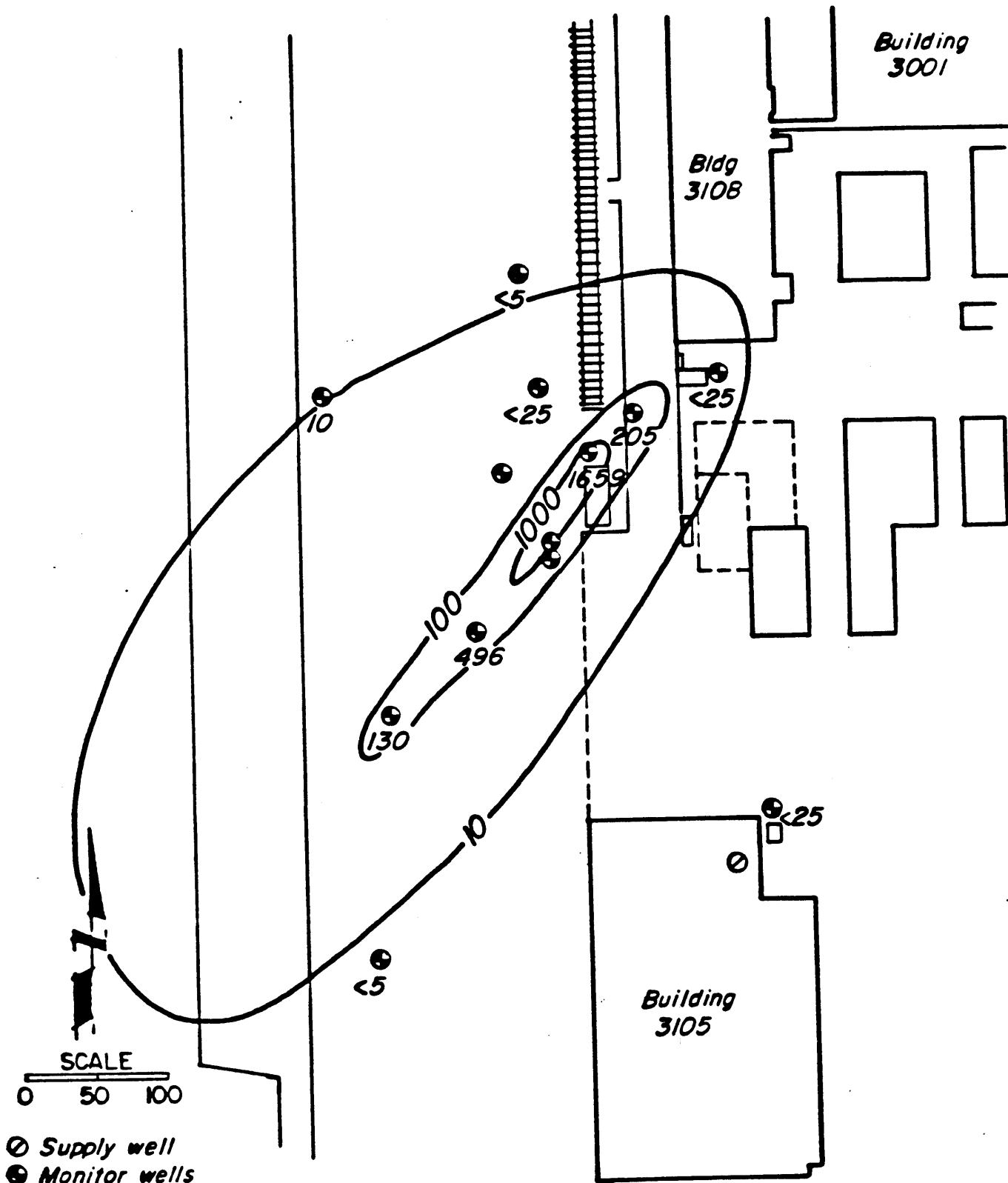


FIGURE 8-2



BENZENE CONCENTRATIONS
(ug/l)
SOUTHWEST TANK AREA

FIGURE 8-3



TOTAL XYLENES CONCENTRATIONS
(ug/l)
SOUTHWEST TANK AREA

FIGURE 8-4

b) North Tank Area. Fuel contamination was first reported in the existing wells installed by A.L. Burke (installed during underground storage tank investigations), well numbers MM-1 through MM-3. Tulsa District COE installed five additional wells (wells 1-26, 1-27, 1-30, 1-31, and 1-32) to further define the extent of fuel contamination. Water and fuel depths have been periodically measured and fuel is present in 7 of the 8 wells. The elevations of the water and fuel (from October 1987 measurements) are listed in Table 8.13. An isopach of the fuel measurements is shown in figure 8-5. It is noted that large amounts of fuel are shown above the water in several wells. The thickness of fuel floating in the formation is probably much less than measured in the wells because fuel product will thicken in the wells. Measured fuel levels in wells can be 4 to 7 times greater than in the formation. A volume of fuel product in the range of 6,000 to 12,000 gallons is estimated to be floating on the groundwater. An analysis of a fuel sample from well 1-30 indicates the product is fuel oil. Some diesel may be present also. Tank 3404 contains fuel oil and is probably leaking. Water samples from the wells indicate the water beneath the fuel product is contaminated with benzene, toluene, and xylene in maximum concentrations of 260, 390, and 780 ug/l, respectively. The plume of contaminated groundwater generally follows the same shape as the fuel plume. The concentrations of benzene, toluene, and xylene are shown in figures 8-6 through 8-8 and also drawings 13, 14, and 15.

TABLE 8.13
Elevations of Groundwater and Fuel¹

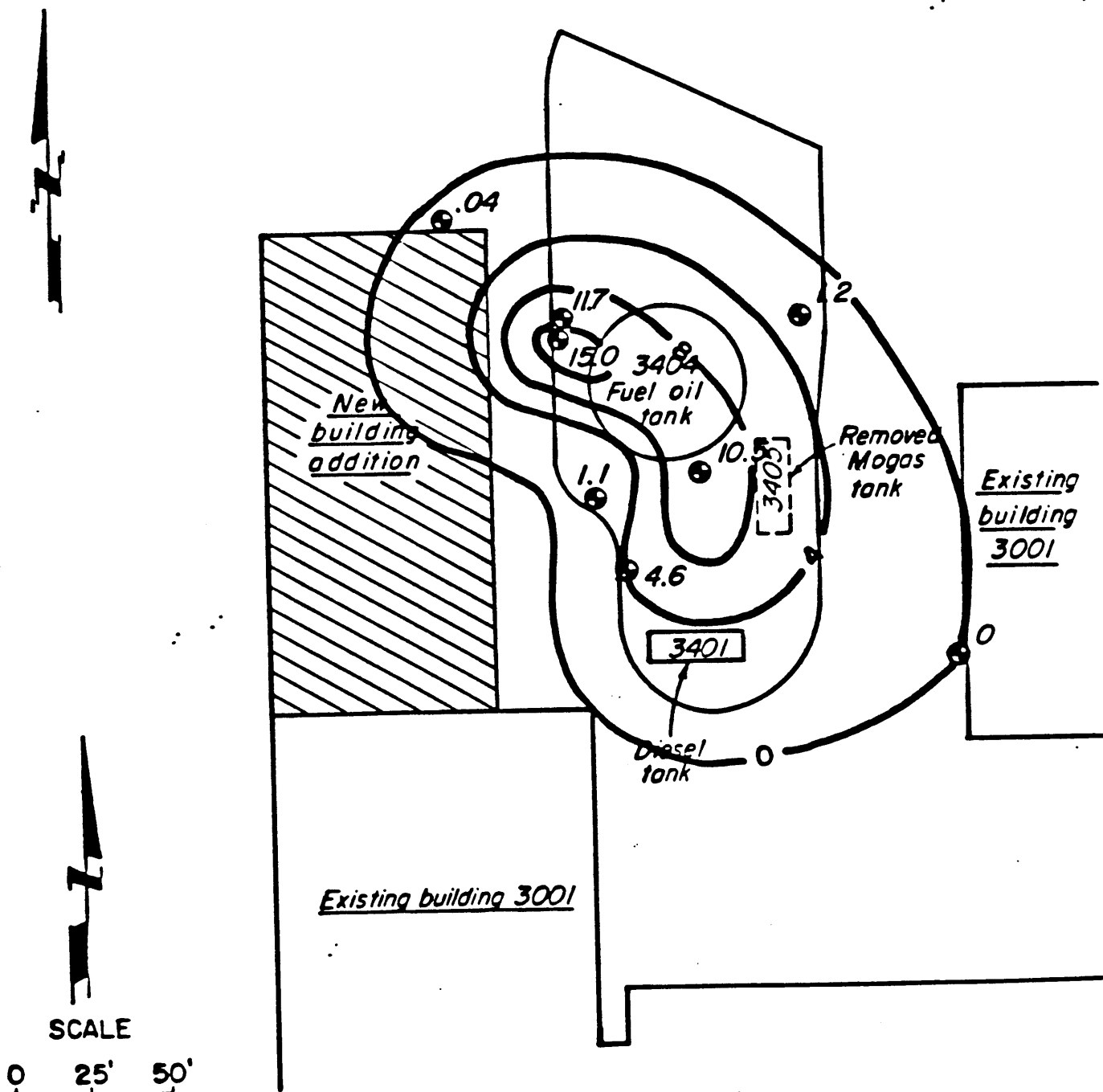
<u>Well Number</u>	<u>Ground Surface Elevations</u>	<u>Top of Fuel Elevation</u>	<u>Top of Water Elevation</u>	<u>Amount of Fuel (Ft)</u>
1-26	1272	1258.1	1257.0	1.1
1-27	1273	1261.0	1259.8	1.2
1-30	1272	1260.0	1248.3	11.7
1-31 ²	1271	1259.8	1259.8	0.04
1-32	1274	ND ³	1269.6	ND
MM-1	1272	1258.9	1254.3	4.6
MM-2	1272	1257.5	1247.0	10.5
MM-3	1272	1260.4	1245.4	15.0

¹ Measurements made in November 1987 (except well 1-31).

² Measurement made in March 1987. Well plugged due to nearby construction.

³ ND - Not detected

● Monitor wells
LO Feet of fuel above groundwater



FUEL ISOPACH
NORTH TANK AREA

FIGURE 8-5

● Monitor wells

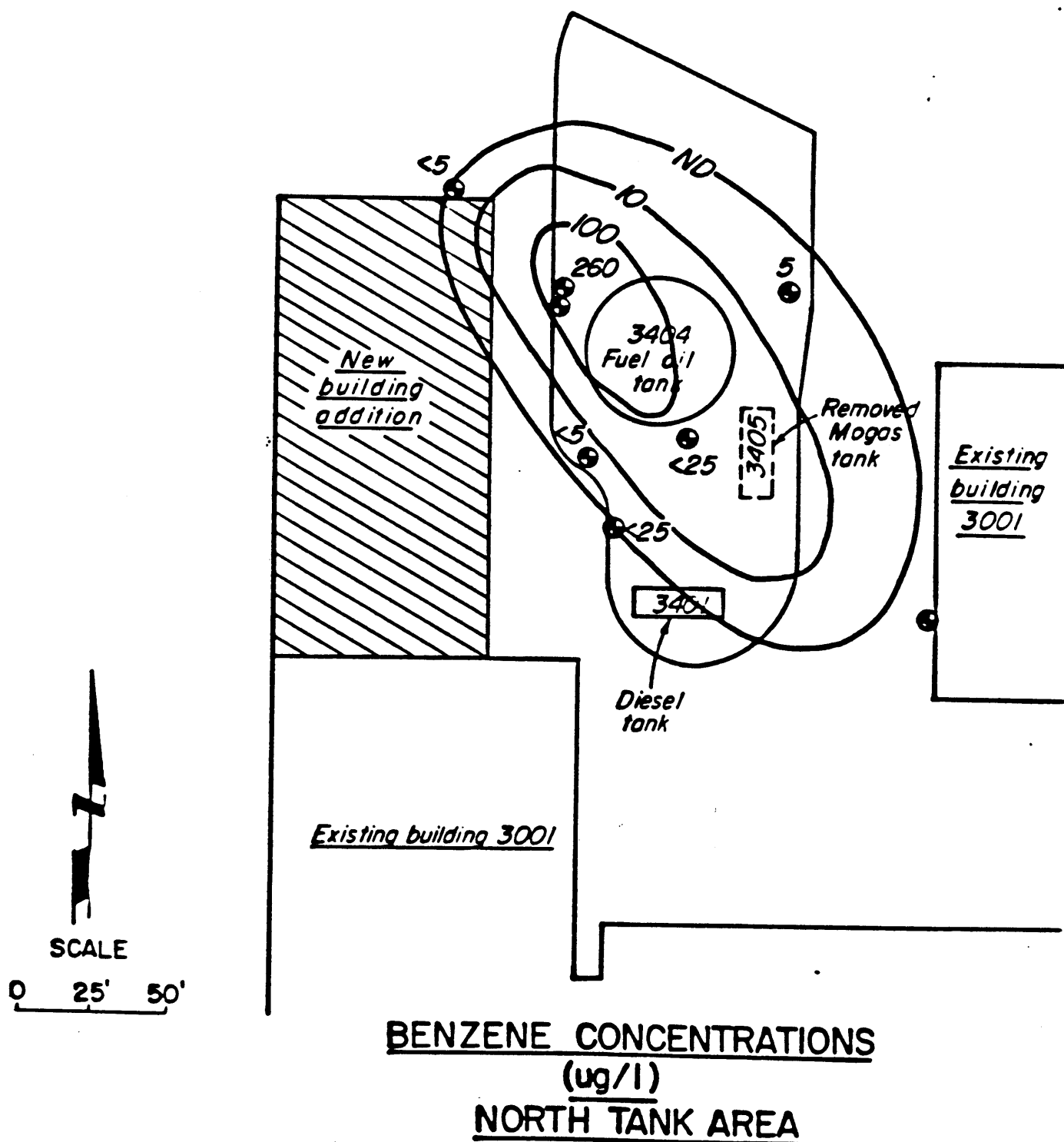
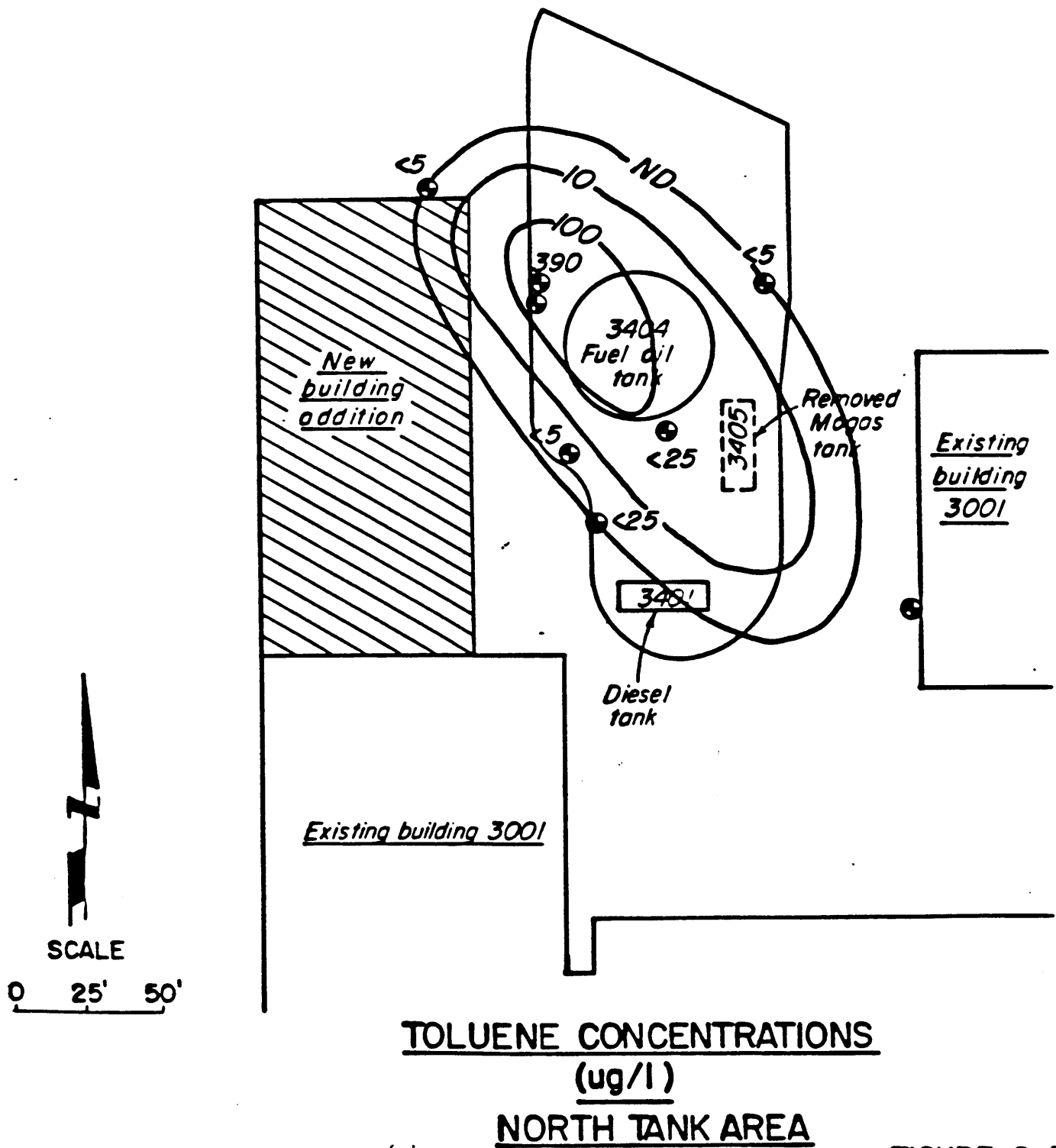
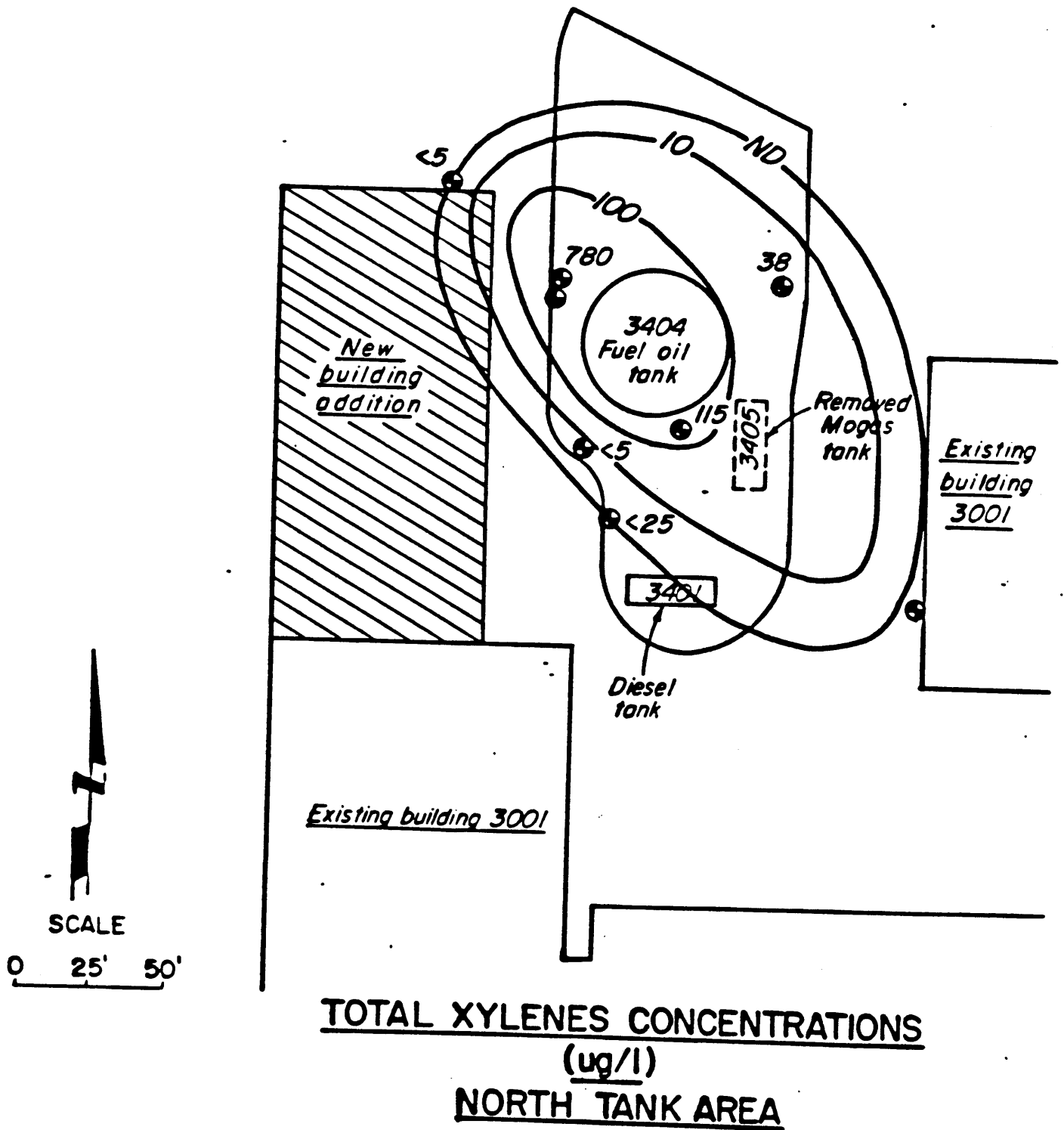


FIGURE 8-6

● Monitor wells
ND Not detected



● Monitor wells
ND Not detected



2) Top of Regional Aquifer. The monitoring wells installed in the top of the regional aquifer zone are listed in Table 8.1. Results of the groundwater analysis (Appendix G) show the presence of organic compounds and heavy metals in this zone. Table 8.14 lists the compounds and metals detected, the detection frequency, their range of concentrations, and the well locations of the maximum concentrations. The concentrations of TCE, 1,2-DCE, and Cr in the top of the regional zone are generally lower beneath the building than in the perched zone. PCE concentrations are slightly higher in the top of regional zone. The other compounds with significant contaminant plumes are 1,2-DCE and PCE and other significant metals are Ba and Pb. Table 8.15 lists the contaminants with significant plumes, the approximate plume areas, the quantity of contaminant, and the appropriate drawing number for each.

As shown on the plume drawings, TCE, 1,2-DCE, PCE, Cr, and Pb, contain elevated concentrations in an area northeast of the building (wells 1-11A and 19A). Also, concentrations of chlorobenzene and vinyl chloride were 940 and 530 ug/l in well 1-11A. Chlorobenzene and vinyl chloride are not present in high concentrations at the remainder of the site. The area is hydraulically upgradient from the building and contaminants have apparently migrated from a source other than the building. The source may be an industrial waste line, the industrial waste treatment plant, or an off-Base source.

Table 8.14
Compounds and Metals Detected with Maximum
Concentrations and Well Locations in
Top of Regional Zone

Compound	Detection Frequency	Concentration Range (ug/l)	Average Conc (ug/l)	Max. Conc. Well Location
TCE	17/25	<5 - 30,000	2330	34B
1,2-DCE	14/25	<5 - 1,400	123	1-11A
PCE	5/25	<5 - 1,200	94	33B
Toluene	5/25	<5 - 84	6	1-13A
1,2 DCA	5/25	<5 - 300	40	33B
Di-n-butyl phthalate	3/10	<10 - 300	41	19A
Phenol	5/10	<10 - 86	23	21A
Bis(2-Ethylhexyl)phthalate	5/10	<10 - 42	19	23A
1,1 DCE	4/25	<5 - 12	8	34B
Chlorobenzene	3/25	<5 - 940	42	1-11A
Vinyl Chloride	2/25	<10 - 530	29	1-11A
Acetone	13/25	<5 - 1400	86	1-6A
Total Metals	Detection Frequency	Conc. Range (mg/l)	Average Conc (mg/l)	Max. Conc. Well Location
Cr	27/33	<.01 - 1.7	0.168	34B
Ba	18/23	<.50 - 24	2.6	1-13A
Pb	21/23	<.01 - .41	.09	1-13A
Ni	23/23	.03 - .53	.07	1-13A

Table 8.15
Significant Contaminant Plumes in
Top of Regional Zone

<u>Contaminant</u>	<u>Approximate Area (acres)</u>	<u>Quantity</u>	<u>Drawing</u>
TCE	181	430 gal	21
1,2 DCE	138	50 gal	22
PCE	30	4 gal	23
Acetone	160	55 gal	24
Cr	153	300 lb	25
Ba	132	9500 lb	26
Pb	118	200 lb	27
Ni	73	200 lb	28

The highest concentration of TCE (30,000 ug/l) was detected beneath the building (well 34B) in the same location as in the perched zone. The compound is spread beneath the building and westward, beyond the west monitoring wells as shown by drawing 21. Well 1-28A contained 360 ug/l at the time of sampling. Additional wells to better define the plume in this area are not planned until remedial cleanup limits are established. However, two monitoring wells at the POL facility (which are approximately 400 feet northwest of the site) will be analyzed for TCE concentrations. Contaminant movement is generally toward the west and south in the direction of groundwater flow. TCE is also present with a concentration of 1100 ug/l in well 1-11A and 490 ug/l in well 19A. The highest concentration of 1,2 DCE was 1400 ug/l in well 1-11A. The plume has a similar shape to the TCE. PCE is present primarily beneath the building (drawing 24) with the highest concentration detected in well 33B. A high concentration of PCE was also present northeast of the building in well 1-11A. Cr was present throughout the site in concentrations above background levels (<.010 mg/l). The highest concentration of total Cr (1.7 mg/l) was detected in well 34B and the plume is spread beneath the building and generally toward the west. Pb is significantly present at the site with total concentrations above the background levels of .048 mg/l. The Pb plume (drawing 28) is shaped similar to the Cr plume, indicating movement toward the west and south. Ba is present at the site with concentrations ranging from 24 to less than 0.5 mg/l. The Ba is spread in a similar fashion as the Cr and Pb (drawing 27), with higher concentrations beneath or near the building limits. Therefore, Ba appears to be a result of the operations within the building rather than natural occurrences in the aquifer.

High pH values are present in the top of regional zone with values as high as 12.9. Drawing 29 shows a contour map of the pH values. The pH values in the perched zone ranged from 6.2 to 9.6, which is in the range of background values. Additional studies will be conducted to investigate this anomaly.

3) Regional Aquifer Zone. Groundwater samples from the regional zone were obtained from the monitoring wells listed on Table 8.1. Laboratory test results (Appendix G) from these samples indicate some of the same compounds and metals are present as in the perched and top of regional zones with generally lower concentrations. The compounds and metals detected are listed in Table 8.16

Table 8.16
Compounds and Metals Detected with Maximum
Concentrations and Well Locations in Regional Zone.

Compound	Detection Frequency	Conc. Range (ug/l)	Average Conc (ug/l)	Max. Conc. Well Location
TCE	7/11	<5 - 1000	160	34C
1,2-DCE	4/11	<5 - 46	13.5	32C
PCE	2/11	<5 - 28	7.3	32C
Methylene Chloride	2/11	<5 - 15	4.4	33C
Benzene	1/11	<5 - 430	41	25C
1,2 DCA	1/11	<5 - 7	2.9	32C
Toluene	3/11	<5 -13,000	1210	25C
Xylene	2/11	<5 - 7	25	1-13C
Acetone	3/11	<10- 100	21	1-13C

Metals	Detection Frequency	Conc. Range (mg/l)	Average Conc (mg/l)	Max. Conc. Well Location
Cr	8/11	1.2	.34	34C
Ba	8/11	27	8.0	1-14C
Pb	11/11	.40	.21	1-14C
Cd	8/11	.013	.011	35C
Ni	11/11	1.9	.35	1-15C

along with the detection frequency, range of concentrations and the well locations of the maximum concentrations. TCE, 1,2-DCE, and PCE have significant plumes which are contained primarily within the north portion of the building. Cr, Pb, Ni, and Ba have significant plumes also. Table 8.17 lists these contaminants, their plume areas, contaminant quantities, and corresponding drawing numbers. The other contaminants present were detected in low levels locally (in one or two wells) and are not spread throughout the site. Toluene is present in well 25C with a concentration of 13,000 ug/l. This well is in the area of the southwest tank area, where toluene is also present in the perched zone. Toluene was not detected in the top of the regional zone below the southwest tank area. An additional monitoring well will be installed in the downgradient location (well 1-45), shown on drawing 1, to further define the extent of toluene in this zone. As shown by the plume drawings, the contaminants are defined in the horizontal direction. TCE and Cr contained concentrations of 1000 and 1200 ug/l respectively at well 34C. An additional well (well 34D) is installed below this aquifer zone and screened from 218 to 253 feet to monitor the next massive, water-bearing sandstone in the aquifer. Results from this well, which are summarized in Table 8.18, indicate that the vertical extent of contamination is adequately defined. Drawings 38 and 39 illustrate the TCE plume in cross sectional view and drawings 40 and 41 illustrate the total Cr plume in cross sectional view.

Table 8.17
Significant Contaminant Plumes in Regional Zone

<u>Contaminant</u>	<u>Approximate Area (acres)</u>	<u>Quantity (gal)</u>	<u>Drawing</u>
TCE	78	13 gal	30
1,2 DCE	54	1 gal	31
PCE	13	<1 gal	32
Cr	145	3201b	33
Pb	NA	NA	34
Ba	NA	NA	35
Ni	NA	NA	36

Table 8.18
Results of Well 34D

<u>Compound</u>	<u>Concentration Detected (ug/l)</u>
TCE	7
1,2 DCE	1
PCE	2
Methylene Chloride	6
1,1,1-TCA	1
<u>Metals</u>	<u>Concentration Detected (mg/l)</u>
Cr	.44
Pb	.34
Ni	.38
Zn	1.70

4) Producing Zone. The water quality in the producing zones of the aquifer were analyzed in the vicinity of Building 3001 by sampling and testing water supply wells 13, 14, 15, and 16. The well locations are shown on drawing 1 and complete laboratory results are contained in Appendix G. Water supply well 17, which is located in the vicinity, was not sampled because it is out of service. Wells 15 and 16 contain low levels of TCE (0.7 and 1.9 ug/l respectively) and well 16 also contains 1,2-DCE and PCE (1.9 and 0.7 ug/l respectively). Well 17 is probably contaminated also since it is in the vicinity of some contaminant plumes in the top of the regional aquifer. Observations of three supply wells while pumping indicated that, although the water supply wells greatly influenced each other, they had very little effect on the upper contaminated groundwater zones. Therefore, contamination apparently entered these wells by vertical migration from the top of the wells. Wells 18 and 19, which were recently plugged, contained TCE and PCE. These wells were located (drawing 1) within the horizontal limits of the TCE and PCE plumes and the poor condition of these wells allowed for their contamination. As shown on drawings 21, 22 and 23, the TCE, 1,2-DCE, and PCE contamination plumes at the top of the regional aquifer extend over water supply wells 15, 16, and 17.

8.4 Chemical Character of Soil. Soil samples were collected from eight borings drilled inside the north portion of Building 3001 (in the industrial shop areas) during the fire-damaged area investigations (Appendix B). Samples were taken from soil adjacent to some abandoned pits and in areas of required excavations. The samples were analyzed for total metals, EP toxicity, volatile organics, and semi-volatile organics. The results of laboratory analyses are listed in Table 2 of Appendix B. A summary of the organics and metals detected is shown in Table 8.19.

Table 8.19
Summary of Organics and Metals Present in
Soil Samples Beneath Building 3001

<u>Organic Compounds</u>	<u>Maximum Concentration (ug/kg)</u>	<u>Location</u>	<u>Depth (ft)</u>
TCE	120,000	E105	5.0-6.0
1,1,1-TCA	5200	W83	5.0-6.0
Methylene Chloride	2.11	E105	5.0-6.0
1,1-DCA	2.1	W83	14.0-15.0
1,2 DCE	.300	A87	9.0-10.0
PCE	4.21	W83	14.0-15.0
1,1,2-TCA	1.92	W83	14.0-15.0
Trichlorofluoromethane	.102	W83	14.0-15.0
chloroform	5.7	W83	14.0-15.0
Methyl ethyl Ketone	7.3	W88	10.0-20.0
Acetone	41	W88	10.0-20.0
Benzene	73,500	E105	5.0-6.0
Chlorobenzene	730	E105	5.0-6.0
Para-dichlorobenzene	6.5	K107	1.0-5.0
Meta-dichlorobenzene	2.4	K107	1.0-5.0
ortho-dichlorobenzene	2.4	K107	1.0-5.0
pi-n-butylphthalate	4.6	K107	7.0-7.5
bis(2-ethylhexyl)phthalate	5.2	K107	7.0-7.5
carbon tetrachloride	1080	E105	5.0-6.0
chloroethylvinyle ether	960	E105	5.0-6.0
1,1,2,2,-PCA	45,400	E105	5.0-6.0
toluene	45,100	E105	5.0-6.0
ethylbenzene	33,600	E105	5.0-6.0
<u>Metals</u>	<u>Maximum Concentration (ug/kg)</u>	<u>Location</u>	<u>Depth (ft)</u>
Ba	1,138	R85	9.0-10.0
Cr	5.0(EP Tox)	R85	9.0-10.0
Hg		R85	9.0-10.0
Cd	1,138	R85	9.0-10.0
Cu	29	R85	9.0-10.5
Pb	14	R85	9.0-10.0
Ni	35	R85	9.0-10.0
Zn	66	R85	9.0-10.0

Results indicate that the upper soils and bedrock (above the perched water table) are contaminated in localized areas beneath the building. Contamination resulted from the migration of solvents and metal-laden wastewaters which leached from sources into the groundwater. Although contamination sources have probably been eliminated, contaminated soils in recharge areas will continue to leach into the perched aquifer as recharge water flushes through the soil. Additional soil sampling will be conducted inside the building to better define the concentrations of contaminants within the zone of aeration. This information will be used to evaluate the feasibility of treating the contaminated soil in-situ and to properly model the contaminant transport in the groundwater under groundwater collection alternatives.

a. North Tank Area. Soil samples were collected at the location of well 1-30 (north tank area) and analyzed for heavy metals, volatile organics, and fuel type. The complete laboratory results, including details of the fuel identification methods, are contained in Appendix I. Low concentrations of As, Ba, Cd, Cr, Ni, Pb, Se, and Zn were detected in the samples. The volatile organics detected are listed in Table 8.20. Fuel and diesel were identified in the soil samples. Diesel was present in one sample and fuel oil was present in 10 samples. Xylene was present in 7 of the 10 samples containing fuel oil. Table 8.21 lists the fuels and total xylenes present with the corresponding depths of the samples. Well 1-30, which is adjacent to fuel tank 3404 (figure 3), also contains fuel floating above the groundwater. The bottom of tank 3404 is approximately 24 feet deep. The highest concentrations of fuel oil and xylene are found from depths of 24 to 33 feet, therefore, the tank probably leaks at or near the tank bottom. Tank 3401, a 20,000 gallon steel diesel tank, is located approximately 75 feet south of Tank 3404. One soil sample (12 to 12.5 feet deep) was identified as containing diesel and fuel oil.

Table 8.20
Volatile Organics Detected in Soil Samples
At Well Location 1-30

<u>Compound</u>	<u>Maximum Concentration (mg/kg)</u>	<u>Depth (ft)</u>
Methylene chloride	.330	20.3
Acetone	9.96	24.7-25.2
Chlorobenzene	.015	12.0-12.5
Ethylbenzene	10.13	27.7-28.2
Toluene	7.73	24.7-25.2
Xylene (total)	31.0	24.7-25.2
Styrene	27.0	27.7-28.2

Table 8.21
Summary of Soil Sample Results
at Well Location 1-30

<u>Depth (ft)</u>	<u>Xylene (mg/kg)</u>	<u>Concentration ug C/g Soil</u>	<u>Fuel Type</u>
2-2.5	ND	<100	-
2.5-3.0	ND	<100	-
5.0-5.3	ND	<100	-
5.5-6.0	ND	<100	-
6.5-7.0	ND	<100	-
7.0-7.5	ND	<100	-
9.0-9.5	ND	<100	-
10.0-10.5	ND	<100	-
12.0-12.5	8	19,000	Diesel & Fuel Oil
12.5-13.0	ND	170	Fuel Oil
17.1-17.6	ND	4500	Fuel Oil
17.8-20.3	.53	120	Fuel Oil
20.3-20.8	ND	<100	-
24.2-24.7	17.	120,000	Fuel Oil
24.7-25.2	31.	130,000	Fuel Oil
27.2-27.4	18.	140,000	Fuel Oil
27.7-28.2	22.00	400,000	Fuel Oil
31.7-32.2	20.00	140,000	Fuel Oil
32.5-33.0	10.475	110,000	Fuel Oil
35.1-35.6	ND	<100	-
37.1-37.6	.082	<100	-

ND - Not Detected

ug C/g Soil = micrograms of carbon per gram of soil.

Soil samples were also collected at well locations 1-26, 1-27, 1-29, and 1-31 and analyzed for noticeable fuel odor. These results are listed in Table 8.22. Fuel odors in the upper zone, above the groundwater, were noticeable in zones of fill material. The fill materials, placed during underground tank and utility construction, may allow fuel vapor movements due to a higher permeability of the fill compared to the natural clays and sands. Vapors from fuel contaminated sites are known to migrate long distances around utility lines. During the underground storage tank investigations (ref. 3), soil samples were collected at well locations MM-1 through MM-3 and also at two boring locations, BM-1 and BM-2. These samples were analyzed for benzene, toluene, and xylene (BTX) and total hydrocarbons. The results are listed in Table 8.23. The perched groundwater table is found at approximately 15 feet deep. Most hydrocarbons were detected in samples below the top of the water table, however, some fuel contamination is present in the soils above the perched water.

Table 8.22
Fuel Detection in Soil Samples

<u>Well Number</u>	<u>Ground Surface Elevation</u>	<u>Sample Depth Feet</u>	<u>Soil Classification</u>	<u>Fuel Detection</u>
1-26	1272	0.0-3.0	CL	ND
		3.0-7.0	CL	P
		7.0-9.5	SP (Fill)	P
		9.5-12.0	SM	ND
		12.0-14.0	SS	ND
		14.0-17.0	SS	ND
1-27	1273	0.0-1.0	CL	ND
		1.0-2.0	SC	ND
		2.0-4.0	SC	ND
		4.0-8.5	ML (Fill)	P
		8.5-9.3	SP (Fill)	P
		9.3-24.0	SS	ND
1-30	1272	11.0-11.4	SC	ND
1-31	1271	0.0-4.0	CL	ND
		4.0-9.0	CL	ND
		9.0-11.0	SC	ND
		13.0-17.0	SS	P
		17.0-20.0	SH	ND

ND - Not Detected
P - Present

Table 8.23
Results of Soil Samples from UST Investigations (mg/kg)¹

<u>Boring No.</u>	<u>Benzene</u>	<u>Toluene</u>	<u>Xylenes</u>	<u>Total Hydrocarbons</u>
BM-1 8'	<1.0	<1.0	<1.0	5.0
BM-1 15'	<1.0	<1.0	<1.0	3301.0
BM-1 20'	<1.0	<1.0	<1.0	6495.0
BM-1 25'	<1.0	<1.0	<1.0	7770.0
BM-2 8'	<1.0	<1.0	<1.0	<1.0
BM-2 15'	<1.0	<1.0	<1.0	2106.0
BM-2 20'	<1.0	<1.0	<1.0	18033.0
BM-2 25'	<1.0	<1.0	<1.0	40038.0
MM-1 8'	<1.0	<1.0	<1.0	<1.0
MM-1 15'	<1.0	<1.0	<1.0	<1.0
MM-1 20'	<1.0	<1.0	<1.0	<1.0
MM-2 8'	<1.0	<1.0	<1.0	<1.0
MM-2 15'	<1.0	<1.0	<1.0	10,050.0
MM-2 20'	<1.0	<1.0	<1.0	26,173.0
MM-2 25'	<1.0	<1.0	<1.0	60,229.0
MM-3 8'	<1.0	<1.0	<1.0	281.0
MM-3 15'	<1.0	<1.0	<1.0	253.0
MM-3 20'	<1.0	<1.0	<1.0	5.0
MM-3 26.5'	<1.0	<1.0	<1.0	48,936.0

¹ Underground Storage Tank Investigations by A.L. Burke Engineers, Inc.
(Ref. 3)

b. Southwest Tank Area. Soil samples collected in this area during the UST Investigations were analyzed for BTX and total hydrocarbons (Ref. 3). Samples were collected from well locations M-1 through M-7 and borings B-1 through B-20 at selected locations (to depths of 35 feet). The locations of these wells and borings are shown on figure 8-9. The results of the laboratory analyses are included in Appendix J. Significant contamination was not observed in the upper soils (above the groundwater), but only at depths within the (greater than 15 feet) perched aquifer. This indicates the contaminant spread is occurring within the groundwater aquifer and any soil contamination is in localized areas (probably adjacent or beneath the abandoned fuel tanks, 3140 through 3144 and 3146 and 3147). The existing contents of the gasoline tanks are unknown.

B. Industrial Waste Treatment Plant

Site Description: The Building 3001 site includes the building complex (covering 50 acres), two adjacent underground storage tank areas, and the surrounding areas encompassed by the lateral extent of the contaminant plume. The site is located near the north boundary of the Base and covers an area of approximately 220 acres. The underground storage tank areas include one site immediately north of the Building and one site southwest of the building, immediately southwest of the Building 3108. The sites are referred to as the north and southwest tank areas.

Contaminant Summary: A summary of results from groundwater monitoring wells at the site is presented on the following pages.

Industrial Waste Treatment Plant

Perched Aquifer

WELL NO.	1-49B	1-50B	1-51B	1-52B	1-53B	1-11B	19B	22B
DATE SAMPLED	3-23-88	3-22-88	3-23-88	3-23-88	3-22-88	10-15-87	10-27-87	10-29-87
Vinyl chloride	<10	70	<10	<10	<10	<2	<10	<2
1,1-Dichloroethane	5J	19	<5	3J	<5	<2	3.3	<2
1,2-Dichloroethane	23	200	<5	<5	<5	<2	<5	<2
Trichloroethene	66	32	<5	<5	<5	<2	32	<2
Tetrachloroethene	50	96	<5	<5	3J	<2	2.7	<2
Chlorobenzene	54	650	<5	<5	<5	<2	<5	<2
1,3-Dichlorobenzene	<20	<10	<10	<10	<10	<20	<10	<10
1,4-Dichlorobenzene	71	20	<10	2J	<10	<20	<10	<10
1,2-Dichlorobenzene	<20	13	<10	<10	<10	<20	<10	<10
2-Chloronaphthalene	<20	11	<10	<10	<10	<10	<10	<10
Bis (2-ethylhexyl) phthalate	9J	<10	14	8J	<10	<2	3.3	<5
Chloroform	41	<5	<5	<5	<5	<2	8.2	<5
1,1,1-Trichloroethane	6	22	<5	<5	<5	7.8	<5	2.4
Benzene	46	10	<5	<5	<5	3.3	<5	<5
Toluene	49	<5	<5	<5	<5	<10	<10	<10
Phenol	120	<10	<10	<10	<10	<10	<10	<10
2-Chlorophenol	130	<10	<10	<10	<10	<10	<10	<10
m-Nitrosodipropylamine	74	<10	<10	<10	<10	<10	<10	<10
1,2,4-Trichlorobenzene	76	<10	<10	<10	<10	<10	<10	<10
p-Chloro-m-cresol	100	<10	<10	<10	<10	<10	<10	<10
Acenaphthylene	<20	<10	<10	<10	<10	<10	<10	<10
Acenaphthene	110	<10	<10	<10	<10	<10	<10	<10
4-Nitrophenol	140	<50	<50	<50	<50	<50	<50	<50
2,4-Dinitrotoluene	88	<10	<10	<10	<10	<10	<10	<10
Pentachlorophenol	87J	<50	<50	<50	<50	<50	<50	<50
Pyrene	100	<10	<10	<10	<10	<10	<10	<10
1,2-Dichloropropane	<5	<5	<5	<5	<5	<2	<5	<5
Diethyl phthalate	<20	<10	3J	<10	4J	<10	<10	<10

NOTE: All units in ug/l.

Industrial Waste Treatment Plant

Top of Regional Aquifer

WELL NO.	1-49A	1-50A	1-51A	1-52A	1-53A	1-11A	19A	22A
DATE SAMPLED	3-23-88	3-22-88	3-23-88	3-23-88	3-22-88	10-15-87	10-27-87	10-30-87
Vinyl chloride	120	300	420	<10	<10	58	<10	<10
1,1-Dichloroethane	15	52	88	<5	<5	<2	4.8	<5
1,2-Dichloroethane	240	920	1700	<5	<5	220	6.3	<5
Trichloroethene	210	790	530	<5	3J	300	150	<5
Tetrachloroethene	8	120	140	<5	<5	29	2.2	<5
Chlorobenzene	820	890	910	8	<5	<2	<5	2.5
1,3-Dichlorobenzene	3J	6J	8J	<10	<10	<20	<20	<20
1,4-Dichlorobenzene	76	88	70	3J	<10	<20	<20	<20
1,2-Dichlorobenzene	130	270	198	5J	<10	<20	<20	<20
2-Chloronaphthalene	4J	<10	<10	<10	<10	<20	<20	<20
Bis (2-ethylhexyl) phthalate	20	<10	11	59	11	<2	<10	<10
Chloroform	<5	<5	9	<5	<5	<2	<5	<5
1,1,1-Trichloroethane	<5	19	11	<5	<5	22	<5	<5
Benzene	6	17	12	<5	<5	130	<5	<5
Toluene	<5	5J	5J	<5	<5	5	<5	<5
Phenol	<10	<10	<10	<10	<10	<10	<10	<10
2-Chlorophenol	<10	<10	<10	<10	<10	<10	<10	<10
n-Nitrosodipropylamine	<10	<10	<10	<10	<10	<10	<10	<10
1,2,4-Trichlorobenzene	<10	<10	<10	<10	<10	<10	<10	<10
p-Chloro-m-cresol	<10	<10	<10	<10	<10	<10	<10	<10
Acenaphthylene	<10	<10	<10	<10	<10	<10	<10	<10
Acenaphthene	<10	<10	<10	<10	<10	<10	<10	<10
4-Nitrophenol	<50	<50	<50	<50	<10	<10	<10	<10
2,4-Dinitrotoluene	<10	<10	<10	<10	<10	<10	<10	<10
Pentachlorophenol	<50	<50	<50	<50	<50	<10	<50	<50
Pyrene	<10	<10	<10	<10	<10	<10	<10	<10
1,2-Dichloropropane	4J	39	39	<5	<50	10	<50	<50
Diethyl phthalate	<10	<10	<10	<10	<10	<10	<10	<10

NOTE: All units in ug/l.

C. Fuel Farm

Site Description: The Fuel Farm, formerly an underground fuel storage facility, has been converted to an above-ground storage site. There is a subsurface fuel product plume consisting of approximately 10,000 gallons floating on top of perched groundwater at the site. The groundwater is contaminated with minor amounts of benzene, xylene, and toluene. The underground tanks have been cleaned and backfilled with sand and bentonite. approximately 1200 gallons of fuel have been removed from the site by August 1988.

Contaminant Summary: Contaminants at the Fuel Farm include primarily those related to fuel use. Benzene, toluene, and xylene concentrations range to 9570, 38,000, and 110,000 ppb respectively in the groundwater. Table 1 summarizes BTX concentrations at the site.

Table 1
TINKER FUEL FARM
CONTAMINANT SUMMARY
GROUNDWATER CONCENTRATIONS

WELL	BEGINNING			ENDING			CHANGE			RANGE OVER PERIOD OF RECORD		
	BENZENE	TOLUENE	XYLENE	BENZENE	TOLUENE	XYLENE	BENZENE	TOLUENE	XYLENE	BENZENE	TOLUENE	XYLENE
4	2786	208	429	2700	22	870	-86	-186	441	74-3177	22-208	ND-31
12	2004	760	3185	2460	92	2330	456	-668	-855	2004-7676	92-7500	860-1
14	ND*	ND	ND	ND	ND	ND	N/A**	N/A	N/A	ND	ND	N
24	5250	13715	2218	2300	5400	3130	-2950	-8315	912	862-5250	3700-13715	1005-
26	1110	15956	5185	3000	10000	2740	1890	-5956	-2445	1110-9570	2000-38000	ND-71

*NOT DETECTED

**NOT APPLICABLE

NOTE: CONCENTRATIONS IN ppb

D. Landfills 1-4

Site Description:

a. Landfill 1. Landfill 1 covers approximately 1 acre and was used from 1942 to 1945. The trenches run east to west and vary from 10 to 25 feet deep. General refuse and dried sludge from the domestic waste treatment plant were disposed of in this landfill.

b. Landfill 2. Landfill 2 covers approximately 20 acres and was used from 1945 to 1952. Trenches are approximately 20 feet deep and are excavated into sandstone. General refuse and small quantities of solvents and paints were disposed of here. This landfill contains Radiological Waste Disposal Site 1030W, a pit where rags and acetone solutions which contained radium were burned. A pond was located on top of Landfill 2.

c. Landfill 3. Landfill 3 covers approximately 8 acres. Trenches are approximately 25 feet deep and are excavated into sandstone. General refuse, paint buckets, insecticide cans, and empty barrels were disposed of here.

d. Landfill 4. Landfill 4 covers approximately 16 acres and was used from 1961 to 1968. General refuse, and small quantities of solvents, paint, and insecticides were disposed of at this site. Trenches were 15 feet deep and excavated into sandstone. High concentrations of OCD, heavy metals, and phenols are present in leachate, which comes from the landfill during periods of wet weather.

Contaminant Summary: A contaminant summary is presented on the following pages.

LANDFILLS 1-4
CONTAMINANT SUMMARY

1. General Conditions. Contaminants detected in the waste, leachate and groundwater include:

CONTAMINANT ABBREVIATIONS

1.1.1TCA -	1.1.1 TRICHLORETHANE	acetone
B2-EP -	BIS<2-ETHYLHEXYL>PHALATE	2-butanone
VC -	VINYL CHLORIDE	2-hexanone
MN-	MANGANESE	naphthalene
DEP-	DIETHYLPHALATE	isophorone
EBP-	ETHYLBENZENE	xylenes
DBP-	DI-N-BUTYLPHTHALATE	phenols
1,2DCE-	1,2 DICHLOROETHENE	toluene
CBZ-	CHLOROBENZENE	benzene
14DCB-	1,4 DICHLOROBENZENE	fluorene
MEC-	METHYLENECHLORIDE	
2,4DMP-	2,4 DIMETHYLPHENOL	
3,3 DCB-	3,3 DICHLOROBENZIDINE	
BBP -	BUTYLBENZYLPHTHALATE	
DOP-	DI-N-OCTYLPHTHALATE	
MP-	METHYLPHENOL	
2-MNP-	2-METHYLNAPHALENE	
EBZ -	ETHYLBENZENE	
B-ACID-	BENZOIC ACID	
TCB -	TRICHLOROBENZENE	
2-CEVE -	2-CHLOROETHYLVINYLETHER	
TETRACE -	TETRACHLORETHENE	

plus barium, cadmium, lead, zinc, mercury.

Concentrations of those contaminants are presented in the spreadsheets. A general location, and site location map are included, as well.

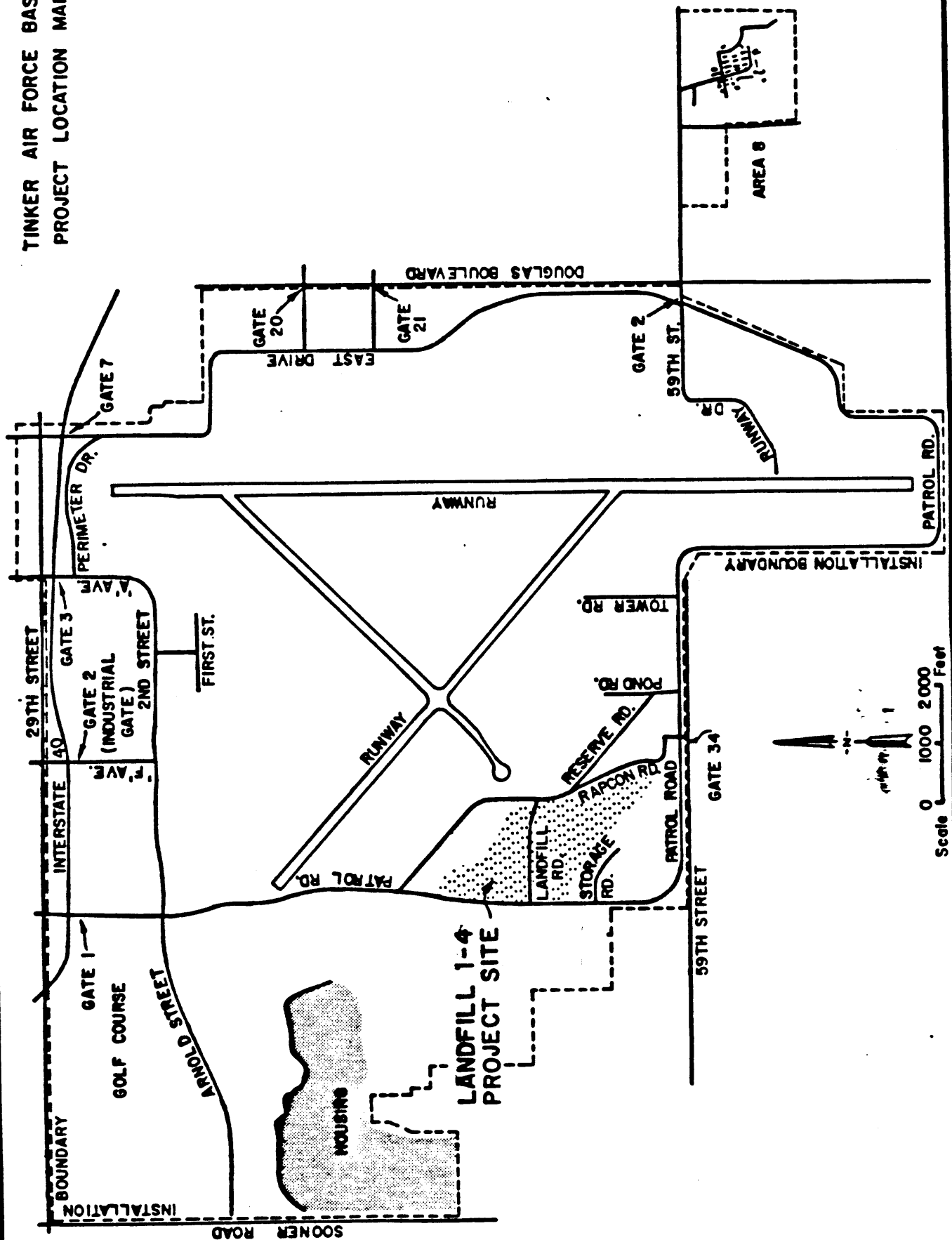
Photos of seep areas on landfill 4 are included. During wet weather, the seeps bubble from all the gas being produced in the landfill waste.

Please return photos.

2. Specific Condition of Sludge Dump Area on Landfill 3.
Location of sludge dump area is shown on Figure 4 on the southern portion of landfill. Concentrations of contaminated soil and water from Hole 3-2 is highlighted in the attached spread sheet. Results from a borehole in the sludge dump area, two different depths, is also attached. There appears to be no free floating hydrocarbon plume in the area. Although, the soil is marbled with a black sludge especially in the 9.5 feet to 11.5 feet depth. The contaminated soil will be removed and treated for

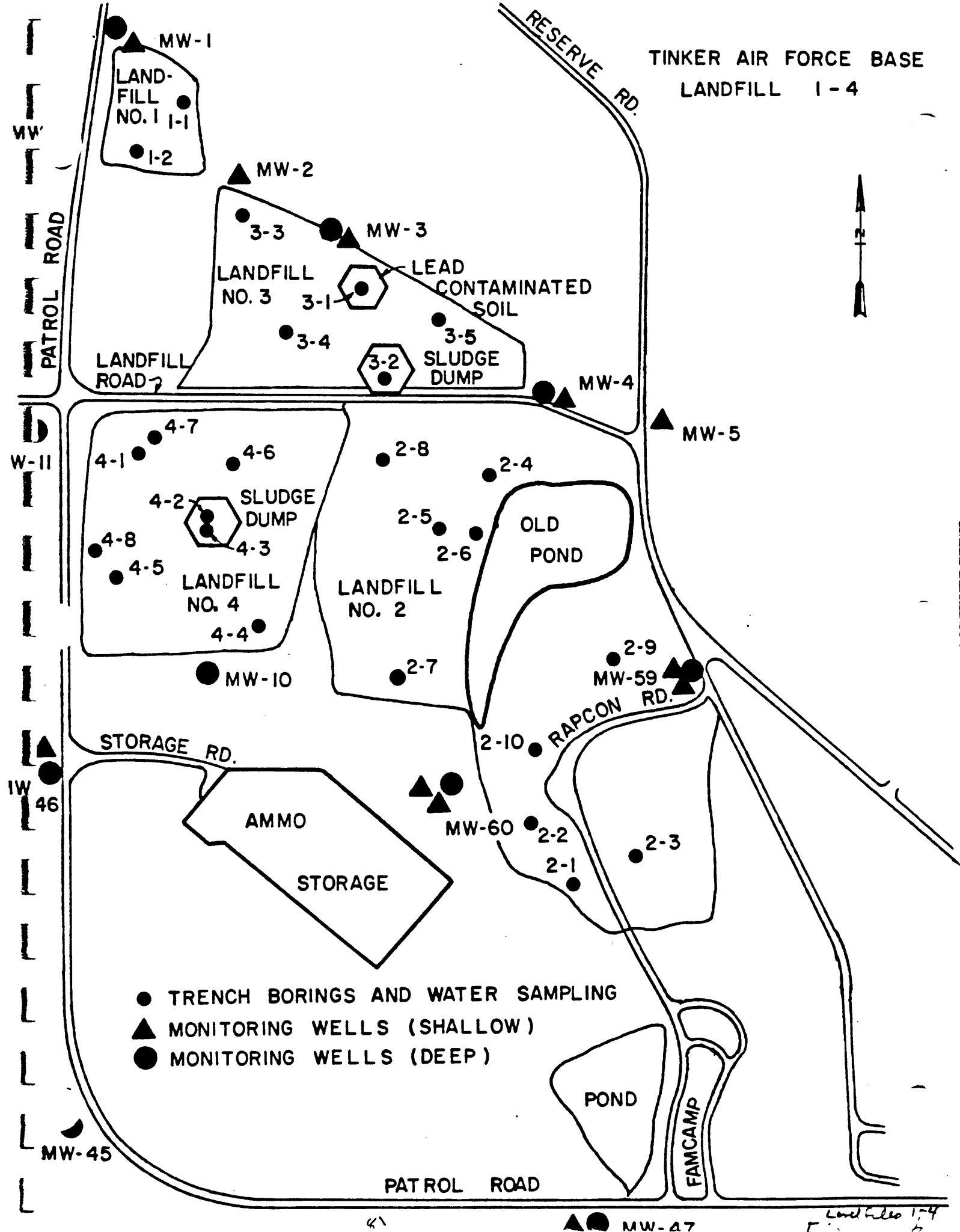
permanent disposal. In order to determine the limits of excavation it will be necessary to drill around the sludge dump area into clean soil at approximately 13 feet. The safety plan needs to be reviewed to insure that the current plan is adequate for this work. Also, any special equipment and/or respirators required to perform the investigation safety should be specified.

TINKER AIR FORCE BASE PROJECT LOCATION MAP



Landfill 1-4

TINKER AIR FORCE BASE LANDFILL 1-4





Southwest Laboratory of Oklahoma

CLIENT: U.S. ARMY CORPS OF ENGINEERS
POST OFFICE BOX 61
TULSA, OKLAHOMA 74121
ATTN: WENDY LANIER, GEOTECH BRANCH

REPORT: SAP2006.36

DATE: 03-23-88

SUBJECT: SAMPLE FOR ANALYSIS

SAMPLE MATRIX: SOIL
SWLO # 18207
DATE SUBMITTED: 03-17-88
SAMPLE IDENTIFICATION: TK 3-2B (9.5 FT DEPTH)

<u>PARAMETER</u>	<u>RESULTS</u>	<u>DATE ANALYZED</u>	<u>ANALYST</u>	<u>METHOD REFERENCE</u>
TOTAL PETROLEUM HYDROCARBONS	7450.0 mg/Kg	03-22-88	MO	503E

STANDARD METHODS, 16TH EDITION

Southwest Laboratory of Oklahoma

BY Robert Harris

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TULSA, OKLAHOMA 74121
ATTN: WENDY LANIER, GEOTECH BRANCH

REPORT: SAP2006.36a

DATE: 03-23-88

SUBJECT: SAMPLE FOR VOLATILE ORGANIC ANALYSIS

SAMPLE MATRIX: SOIL
SWLO # 18207
DATE SUBMITTED: 03-17-88
METHOD: SW846-B240, EPA METHODOLOGY
SAMPLE IDENTIFICATION: TK 3-2B (9.5 FT DEPTH)

RESULTS REPORTED IN ug/Kg or Parts Per Billion (PPB)

<u>VOLATILES</u>	<u>RESULTS</u>	<u>VOLATILES</u>	<u>RESULTS</u>
CHLOROMETHANE	<12500	1,1,2,2-TETRACHLOROETHANE	<6250
BROMOMETHANE	<12500	1,2-DICHLOROPROPANE	<625
VINYL CHLORIDE	<12500	TRANS-1,3-DICHLOROPROPENE	<6250
CHLOROETHANE	<12500	TRICHLOROETHENE	4070000
METHYLENE CHLORIDE	84740	DIBROMOCHLOROMETHANE	<6250
ACETONE	<12500	1,1,2-TRICHLOROETHANE	<6250
CARBON DISULFIDE	<6250	BENZENE	<6250
1,1-DICHLOROETHENE	<6250	CIS-1,3-DICHLOROPROPENE	<6250
1,1-DICHLOROETHANE	<6250	2-CHLOROETHYL VINYLETHER	<12500
TRANS-1,2-DICHLOROETHENE	232240	BROMOFORM	<6250
CHLOROFORM	<6250	2-HEXANONE	<12500
1,2-DICHLOROETHANE	<6250	4-METHYL-2-PENTANONE	117320
2-BUTANONE	<12500	TETRACHLOROETHENE	446900
1,1,1-TRICHLOROETHANE	<6250	TOLUENE	226200
CARBON TETRACHLORIDE	<6250	CHLOROBENZENE	<6250
VINYL ACETATE	<12500	ETHYLBENZENE	19280
BROMODICHLOROMETHANE	<6250	STYRENE	<6250
ACROLEIN	<125000	TOTAL XYLENES	131000
ACRYLONITRILE	<125000	TRICHLOROFLUOROMETHANE	<12500

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REPORT: SAP2006.35

DATE: 03-23-88

SUBJECT: SAMPLE FOR ANALYSIS

SAMPLE MATRIX: SOIL
SWLO # 18206
DATE SUBMITTED: 03-17-88
SAMPLE IDENTIFICATION: TK 3-2B (5 FT DEPTH)

<u>PARAMETER</u>	<u>RESULTS</u>	<u>DATE ANALYZED</u>	<u>ANALYST</u>	<u>METHOD REFERENCE</u>
TOTAL PETROLEUM HYDROCARBONS	3760.0 mg/Kg	03-22-88	MO	503E

STANDARD METHODS, 16TH EDITION

Southwest Laboratory of Oklahoma

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REPORT: SAP2006.35a

DATE: 03-23-88

SUBJECT: SAMPLE FOR VOLATILE ORGANIC ANALYSIS

SAMPLE MATRIX: SOIL
SWLO # 18206
DATE SUBMITTED: 03-17-88
METHOD: SW846-8240, EPA METHODOLOGY
SAMPLE IDENTIFICATION: TK 3-2B (5 FT DEPTH)

RESULTS REPORTED IN ug/Kg or Parts Per Billion (PPB)

<u>VOLATILES</u>	<u>RESULTS</u>	<u>VOLATILES</u>	<u>RESULTS</u>
CHLOROMETHANE	<50	1,1,2,2-TETRACHLOROETHANE	<25
BROMOMETHANE	<50	1,2-DICHLOROPROPANE	<25
NYL CHLORIDE	<50	TRANS-1,3-DICHLOROPROPENE	<25
CHLOROETHANE	<50	TRICHLOROETHENE	778
METHYLENE CHLORIDE	96	DIBROMOCHLOROMETHANE	<25
ACETONE	<50	1,1,2-TRICHLOROETHANE	<25
CARBON DISULFIDE	<25	BENZENE	<25
1,1-DICHLOROETHENE	<25	CIS-1,3-DICHLOROPROPENE	<25
1,1-DICHLOROETHANE	<25	2-CHLOROETHYL VINYLETHER	<50
TRANS-1,2-DICHLOROETHENE	100	BROMOFORM	<25
CHLOROFORM	<25	2-HEXANONE	<50
1,2-DICHLOROETHANE	<25	4-METHYL-2-PENTANONE	<50
2-BUTANONE	<50	TETRACHLOROETHENE	<25
1,1,1-TRICHLOROETHANE	<25	TOLUENE	<25
CARBON TETRACHLORIDE	<25	CHLOROBENZENE	<25
VINYL ACETATE	<50	ETHYLBENZENE	<25
BROMODICHLOROMETHANE	<25	STYRENE	<25
ACROLEIN	<500	TOTAL XYLENES	<25
ACRYLONITRILE	<500	TRICHLOROFLUOROMETHANE	<50

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CONTAMINANT CONCENTRATIONS IN PFB

86

TRENCH WATER	NORTH	EAST	ELEVATION	DEPTH TO WATER	WATER ELEVATION	T.WATER	VC	MEC	ACETONE	TCE	1.1.1 TCA	1,2DCE	TETRACE
1-1	151982.35	2177515.05	1224.39	12.6	1211.79	1-1	ND	ND	13	ND	ND	ND	ND
1-2	151838.29	2177474.71	1223.84	11.41	1212.43	1-2	ND	370	25	ND	ND	ND	ND
2-1	149329.51	2176914.65	1244.84	6.17	1238.67	2-1	ND	ND	50	ND	ND	ND	ND
2-2	149580.49	2176763.24	1239.47	7.41	1232.06	2-2	ND	ND	790	50	ND	50	ND
2-3	149762.42	2176611.95	1239.36	20.18	1219.18	2-3	ND	ND	370	190	ND	670	ND
2-4	150783.92	2176408.94	1238.05	8.17	1229.88	2-4	ND	ND	300	25	ND	ND	ND
2-5	150462.09	2176447.59	1238.09	6	1232.09	2-5	ND	ND	ND	ND	ND	ND	ND
2-6	150419.09	2176060.09	1253.41	6.37	1247.04	2-6	ND	ND	2900	ND	ND	ND	ND
2-7	150551.99	2176311.79	1245.35	2.5	1242.85	2-7	ND	ND	50	ND	ND	ND	ND
2-8	150735.41	2177995.47	1248.33	1.24	1247.09	2-8	ND	ND	330	ND	ND	ND	ND
2-10	149986.27	2176600.66	1234.48	4	1230.48	2-10	610	ND	250	380	ND	3000	ND
3-1	151357.13	2177975.19	1231.63	13.1	1218.53	3-1	ND	ND	ND	ND	ND	ND	ND
3-2	151111.88	2178068.43	1230.22	16.2	1214.02	3-2	540	ND	74000	120000	ND	240000	ND
3-3	151516.54	2177860.24	1233.31	17.88	1215.43	3-3	ND	ND	ND	ND	ND	ND	ND
3-4	151218.11	2177888.46	1230.09	14.85	1215.24	3-4	ND	ND	15	ND	ND	ND	ND
3-5	151280.18	2178261.07	1235.71	2	1223.71	3-5	ND	ND	ND	ND	ND	ND	ND
4-1	105790.86	2177652.79	1244.28	22	1222.28	4-1	6	0	25	4	ND	6	ND
4-2	150558.21	2177754.68	1256.87	5.5	1251.37	4-2	ND	74	28000	MD	ND	ND	ND
4-3	150545.92	2177751.99	1254.26	8	1246.26	4-3	ND	ND	ND	ND	ND	ND	ND
4-4	150343.31	2177641.95	1256.25	4.08	1252.17	4-4	ND	ND	5100	MD	ND	ND	ND
4-5	150501.85	2177413.32	1251.43	0	1251.43	4-5	ND	640	14000	MD	ND	ND	ND
4-6	150680.52	2177650.32	1253.63	4.05	1249.58	4-6	ND	ND	160	MD	ND	ND	ND
4-7	150469.58	2177361.84	1250.01	0	1250.01	4-7	ND	ND	110	MD	ND	ND	ND
4-8	150915.21	2177499.49	1233.74	0	1233.74	4-8	ND	ND	ND	MD	ND	ND	ND
4-9	150557.81	2177341.39	1248.74	0	1248.74	4-9	ND	ND	ND	MD	ND	ND	ND
							MAXIMUM CONCENTRATION	640	74000	120000	0	240000	0
							MINIMUM CONCENTRATION	0	0	0	0	0	0
							AVERAGE CONCENTRATION	43.36	5059.52	4825.46	0	9749.04	0

CONTAMINANT CONCENTRATIONS IN PPB

WELLS	1,2DCA	V-ACETATE	2-BUTANONE	2-CEVE	2-HEXANONE	NAPHTHALENE	ISOPHORONE	2-MNP	XYLENES	PHENOL	TOLUENE	DOP	DBP	EB
1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5	12	ND	11	ND	ND	ND	ND	ND	ND	210	ND	ND	1.9	ND
9	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6	ND
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
OLD 11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
59A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
59B	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
59C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
60A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
60B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
60C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	74	0	11	0	0	0	0	0	0	210	3	0	2.5	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4.11111	0	0.611111111	0	0	0	0	0	0	11.66666	0.166666	0	0.138	0

TRENCH WATER	1,2DCA	V-ACETATE	2-BUTANONE	2-CEVE	2-HEXANONE	NAPHTHALENE	ISOPHORONE	2-MNP	XYLENES	PHENOL	TOLUENE	DOP	DBP	EB
1-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-2	ND	ND	1100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-1	ND	ND	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-2	ND	ND	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-3	ND	ND	1600	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-5	ND	ND	23000	ND	2700	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-6	ND	ND	14000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-7	ND	ND	260	ND	ND	10	ND	ND	26	ND	ND	ND	ND	ND
2-8	ND	ND	9600	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-10	ND	ND	12000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-1	ND	ND	180000	ND	32000	ND	ND	820	ND	15000	ND	ND	ND	ND
3-2	ND	ND	ND	ND	ND	38	ND	ND	ND	ND	ND	ND	ND	ND
3-3	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND
3-4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-5	ND	ND	ND	ND	ND	15	ND	ND	ND	ND	ND	ND	ND	ND
4-1	ND	ND	ND	ND	7000	ND	ND	ND	94	19000	280	ND	ND	6
4-2	ND	1600	41000	1900	ND	ND	ND	ND	ND	ND	ND	ND	ND	71
4-3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-4	ND	ND	1700	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-5	ND	ND	17000	ND	2600	ND	ND	ND	ND	2300	1100	ND	ND	ND
4-6	ND	ND	730	ND	ND	ND	ND	ND	160	ND	ND	ND	ND	ND
4-7	ND	ND	ND	ND	ND	ND	ND	ND	350	ND	ND	ND	ND	ND
4-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	0	1600	180000	1900	32000	38	0	820	350	19000	1100	0	0	71
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	64	11927.6	76	1772.6	2	0	32.8	25.2	1452	81.08	0	0	9.72

CONTAMINANT CONCENTRATIONS IN PPB

WELLS	B2-EP	BBP	BENZENE	CBZ	2,4DMP	2-MP	4-MP	1,2DCB	3,3DCB	1,4DCB	124TCB	FLUORENE	DEP	B-ACID
1	1.1	ND	ND	ND	ND	ND	ND	ND	ND	1.8	ND	ND	2.8	ND
1B	70	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	75	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3A	3.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3B	4	1	ND	ND	ND	ND	ND	13	ND	3	ND	ND	ND	ND
4	3.9	ND	ND	118	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5	0.5	ND	ND	23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11	43	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
59A	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	ND
59B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
59C	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
60A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
60B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
60C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	202.8	1	0	146	0	0	0	13	0	7.8	3	0	172.8	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11.26666	0.05	0	0.11	0	0	0	0.72222	0	0.43333	0.16666	0	9.6	2.77777

OLD

58

TRENCH WATER

	B2-EP	BBP	BENZENE	CBZ	2,4DMP	2-MP	4-MP	1,2DCB	3,3DCB	1,4DCB	124TCB	FLUORENE	DEP	B-ACID
1-1	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-2	ND	ND	ND	50	ND	ND	100	ND	ND	ND	ND	ND	ND	ND
2-1	ND	ND	ND	ND	110	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-2	ND	ND	ND	ND	78	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-4	ND	ND	ND	88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-6	ND	ND	ND	170	ND	ND	ND	ND	ND	ND	ND	ND	ND	620
2-7	ND	ND	ND	50	ND	ND	ND	ND	ND	11	ND	ND	ND	ND
2-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-10	ND	ND	ND	390	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-2	3900	ND	ND	ND	18000	17000	73000	30000	ND	5400	14000	800	800	ND
3-3	ND	ND	71	940	52	ND	ND	ND	ND	29	ND	ND	ND	ND
3-4	ND	ND	61	59	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-5	ND	ND	15	77	ND	ND	ND	ND	ND	15	ND	ND	97	ND
4-1	20	ND	ND	3	19	ND	11000	ND	ND	ND	ND	ND	ND	ND
4-2	2500	ND	ND	89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-3	ND	ND	ND	ND	ND	ND	1300	ND	ND	ND	ND	ND	ND	ND
4-4	ND	ND	ND	ND	<110	ND	2200	ND	ND	ND	ND	ND	ND	960
4-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	750	ND
4-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3900	0	71	940	18000	17000	73000	30000	0	5400	14000	800	800	960
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	256.8	0	5.88	76.8	730.36	680	3504	1200	0	218.2	560	32	66.68	63.2

CONTAMINANT CONCENTRATIONS IN PPB

WELLS	BARIIUM	CHROMIUM	CAD	LEAD	ZINC	HG	TOC	OIL&GREASE	CHLORIDE	SULFATE	MN	IRON	PH
1	4200	190	0	93	1800	ND	3800	ND	50000	2000	2600	34000	7.2
1B	3600	50	ND	70	120	0.26	5700	ND	49000	149000			7.05
2	4200	190	10	93	190	ND	7500	ND	140000	3000			7.33
3A	2800	ND	10	38	93	0.4	6700	ND	70000	3000			6.98
3B	16000	310	ND	130	320	ND	3300	ND	23000	51000	4000	100000	6.08
4	16000	310	ND	35	950	ND	19000	26000	140000	8000			6.94
4B	16000	50	ND	45	20	ND	9400	ND	13000	14000	370	43	12.47
5	2900	110	8	80	45	0.2	3200	ND	78000	71000			7.12
9	800	110	10	80	55	0.3	4000	ND	125000	8000			7.09
10	ND	110	10	80	55	ND	4000	ND	31000	11000			7.26
10	ND	110	3	63	65	ND	5000	ND	48000	62000			7.35
11	6300	65	ND	370	110	ND	2700	ND	54000	62000	9900	480000	7.24
59A	14000	810	10	280	920	ND	2700	ND	42000	92000			7.28
59B	500	340	ND	50	30	ND	2700	ND	97000	296000	100	41000	7.45
59C	2800	170	ND	100	160	0.12	8300	ND	290000	259000	3000	78000	6.64
60A	1000	40	ND	30	60	ND	3800	ND	39000	56000	390	24000	7.16
60B	3600	40	ND	50	72	ND	2800	ND	17000	25000	620	35000	8.08
60C	500	20	ND	50	67	ND	3300	ND	16000	61000	50	18000	7.73
	81000	2915	69	1692	5122	1.28	95200	26000	1322000	1233000	20930	810043	136.45
	0	0	0	30	20	0	0	0	13000	2000	50	43	6.64
	4500	161.9444	3.833333	94	284.5555	0.071111	5288.888	1444.4444	73444.44	68500	2325.555	90004.77	7.580555

TRENCH WATER	BARIIUM	CHROMIUM	CAD	LEAD	ZINK	HG	TOC	OIL&GREASE	CHLORIDE	SULFATE	MN	IRON	PH
1-1	5000	190	120	830	2800	0.96	37000	3000	73000	20000	4500	91000	6.89
1-2	9500	650	210	1200	11000	10	120000	32003200	140000	110000	5800	260000	6.32
2-1	5000	40	25	490	3000	0.39	36000	7000	100000	20000	2800	28000	6.52
2-2	8500	65	110	820	750	0.46	59000	6200	190000	20000	1300	58000	6.16
2-3	980	93	60	90	59	0	29000	3000	170000	52000	1800	91000	6.85
2-4	5600	63	60	290	1400	0.79	200000	3000	590000	150000	2300	1600	6.35
2-5	5000	25	55	70	38	0	66000	2600	450000	3000	750	120000	6.48
2-6	7900	85	55	350	1500	0.61	1700000	45000	650000	230000	12000	230000	6.58
2-7	6800	350	190	1000	2300	2	210000	2400	170000	170000	500	120000	6.55
2-8	6100	18	ND	60	98	0	34000	1200	50000	49000	880	2800	6.45
2-10	2100	ND	ND	48	65	0	27000	0	100000	19000			6.98
3-1	2700	10	ND	50	48	0	49000	0	52000	19000	4700	10000	6.69
3-2	2600	28	28	460	500	0	4300000	550000	450000	0	1300	120000	6.55
3-3	7300	60	33	670	310	1.3	50000	3200	380000	180000	1000	11000	6.11
3-4	250	18	7.5	78	45	0	27000	3600	35000	270000	3000	110000	6.7
3-5	3200	1600	10	820	880	3.1	16000	0	7500	220000	210	3300	5.97
4-1	740	20	0	40	210	0.15	44000	0	240000	170000	37000	130000	7.11
4-2	5000	490	4400	2600	95000	18	9400000	1800000	1100000	720000			5.99
4-3	3400	78	23	110	4000	1.2	960000	69000	190000	197000	3300	180000	6.3
4-4	4300	140	33	200	53000	0.25	6200000	1100000	680000	1000000	34000	1000000	5.94
4-5	5000	30	60	170	2500		6300000	2400	670000	124000	750	25000	6.32
4-6													
4-7													
4-8													
4-9													
	9500	1600	4400	2600	95000	18	9400000	32003200	1100000	1000000	37000	1300000	7.11
	0	0	0	0	38	0	16000	0	7500	0	210	1800	5.94
	4407.72	185.1363	243.8409	474.8181	8547.714	1.9605	1152095.	1695466.66	308928.5	177619.0	5930.5	189635	6.467142

LA 1 FOR SOLIDS FROM LANDFILLS 1-4

SOLID	NORTH	EAST	ELEVATION	PERMEABILITY	SOLID	VC	MEC	ACETONE	TCE	1,1,1 TCA	1,2DCE	TETRACE
1-1	151992.35	2177515.05	1294.39		1-1			1400				
1-2	151838.29	2177414.71	1223.84		1-2			1200				
2-1	149529.51	2178914.65	1244.84		2-1							
2-2	149580.49	2178763.24	1239.47		2-2		200				670	
2-3	149762.42	2178611.95	1239.36		2-3			370	190			
2-4	150783.92	2178408.94	1236.05		2-4		46	1500				
2-5	150462.09	2178447.59	1236.09		2-5		10	<9				
2-6	150419.09	2178060.09	1253.41		2-6		26	2700				
2-7	150551.99	2178311.79	1245.35		2-7		34	2600				
2-8	150735.41	2177995.47	1246.33		2-8		10	1700				
2-9	150233.69	2178919.15	1241.05		2-9							
2-10	149986.27	2178600.66	1234.48		2-10							
2-11	149550.29	2178868.89	1241.48		2-11							
3-1	151357.13	2177975.19	1231.63		3-1	8000						
3-2	151111.68	2178068.43	1230.22		3-2	8300				980	370000	430000
3-3	151516.54	2177860.24	1233.31		3-3	53						
3-4	151218.11	2177868.46	1230.09		3-4							
3-5	151280.18	2178261.07	1225.71		3-5							
3-6	105798.86	2177652.79	1244.28		4-1	14		490				
4-1	150558.21	2177754.68	1256.87		4-2	40		460				
4-2	150545.92	2177751.99	1254.26		4-3	41		1400	2.5			11
4-3	150343.31	2177641.95	1256.25		4-4	35		1200				9
4-4	150501.65	2177413.32	1251.43		4-5			23000				
4-5	150680.52	2177850.32	1253.63		4-6	51		1000				
4-6					MAXIMUM CONCENTRATION	600		23000	3000000	980	370000	430000
					MINIMUM CONCENTRATION	0		0	2.5	980	370000	9
					AVERAGE CONCENTRATION	300	1276.076	3245.833	1500001	980	370000	143340

SOLID	B2-EP	BGP	BENZENE	CBZ	2,4DHP	2HP	4MP	1,2DCB	3,3DCB	1,4DCB	12,1TCB	FLUORENE	DEP	B-ACID
1-1													70	
1-2	235			120										
2-1	1340			460	310									
2-2	820													
2-3	1200			270						55			135	
2-4	5400			38									900	
2-5	1650			17									440	
2-6	500			12										
2-7														
2-8														
2-9														
2-10	340	300												
3-1				8000										
3-2				3200										
3-3	120000			210	31000	9500	43000	210000		40000	24000		1900	
3-4														
3-5	1880													
3-6														
4-1	950			13									650	
4-2	950			300									5200	
4-3				21			750						5100	
4-4	940													
4-5	4500	650		45										
4-6	5100													
	120000	650	ERR 8000	ERR 12	31000	9500	43000	210000	ERR	40000	24000	24000	5200	
	340	300	ERR 12	ERR 12	31000	9500	750	210000	ERR	55	24000	24000	135	
	13708	475	ERR 1200	ERR 1200	31000	9500	21075	210000	ERR	20027.5	24000	24000	2046.4	

ID	1,2DCR	V-ACETATE	2-BUTANONE	2-CEVE	2-HEXANONE	NAPHTHALENE	ISOPHORONE	2-MNP	MYLENES	PHENOL	TOLUENE	DOP	DBP	EB
1-1													1600	
1-2											330		160	
2-1													740	
2-2						690						480	850	
2-3						550							115	
2-4			22			60		47	9					
2-5			1600			80			95	260	58			34
2-6			68		620	435			23					9
2-7			31						14					19
2-8														
2-9														
-10													530	
3-1														
3-2														
3-3			8900	9200	13000	3400		9500	23000		170000			10000
3-4									17000		4			5000
3-5									27					12
3-6														
4-1			130		190				66					57
4-2			800		110				380		120			59
4-3			150		490				160		170			110
4-4			200000		79				310		440			
4-5			10		5600	700		200	3400	5500		215	2600	
4-6			ERR	9200	2.5				190		25			57
	340	ERR	200000	9200	13000	3400	ERR	9500	23000	5500	170000	215	2600	10000
	340	ERR	22	9200	79	60	ERR	47	9	260	4	215	115	9
	340	ERR	23522.33333	9200	2869.057142	935	ERR	3249	3707	2880	28465.33	215	1081.	1700

SOLID	BARIUM	CHROMIUM	CAD	LEAD	ZINK	HG	TOC	OIL&GREASE	CHLORIDE	SULFATE	MN	IRON	PH
1-1	620000	8600	2000	26000	40000	270							7.25
1-2	340000	15000	1400	13000	41000	230							7.21
2-1	330000	110000	15000	3600000	470000	460	5700000						7.1
2-2	400000	19000	5000	67000	55000	150	5000000						7.27
2-3	460000	20000	16000	190000	240000	390	29000	3000	170000	52000	880	31000	7.03
2-4	2600000	25000	6800	36000	110000	1400							6.98
2-5	510000	13000	3100	14000	82000	120							7.18
2-6	120000	17000	5900	21000	99000	520							6.57
2-7	57000	9000	1500	9900	33000	180							7.3
2-8	160000	11000	1300	9100	21000		34000	1200	50000	49000	500	120000	6.45
2-9							8500000						7.54
2-10	380000	17000	840000	77000									7.54
3-1	160000			480000	530000	500	2700000						6.89
3-2	380000	140000	12000	130000	780000	970	20000000						6.93
3-3	330000	380000	200000	1100000	610000	680	230000000						7.34
3-4	710000	48000	51000	150000	2000000								
3-5	310000	42000	29000	150000	2000000								
3-6	530000	12000	47000	51000	120000	590	90000000	0	240000	170000	210	3300000	7.11
4-1	350000	25000	8200	36000	83000	0	44000						7.7
4-2	150000	120000	520000	150000	210000	280							6.86
4-3	370000	640000	40000	75000	41000	140							7.2
4-4	450000	11000	1600	9600	330000	720	260000000						6.86
4-5	480000	18000	5800	61000	140000	520							7
4-6	150000	16000	8000	56000	2000000	1400	260000000	1200	240000	170000	500	3300000	7.7
	4500000	640000	840000	1100000	2000000	0	0	0	0	49000	210	120000	6.45
	57000	9000	1300	9100	21000	0		600	96666.66	109500	355	1710000	7.096666
	711588.	95500	110825	150600	360642.8	508.3333	11327800						

E. Landfill 5

Site Description: Landfill 5 was in operation from 1968 to 1970. Waste disposed of consisted of general refuse with small quantities of industrial wastes. The trenches at the site run from northwest to southwest and are estimated to be 400 feet long, 50 feet wide, and 16 feet deep. Landfill 5 covers and estimated 6 acres and contains approximately 75,000 cubic yards of waste. After the landfill was closed, it was covered with soil and vegetated. The landfill, shown in Drawing 1, is a triangular shape bounded by Tower Road to the west, Patrol Road to the south, and Crutch Creek to the north and east. The ground surface is mounded in the middle of the site. Settlement in the northern trenches has resulted in depressions which allow water to pond.

Contaminant Summary: A contaminant summary is presented on the following pages.

LANDFILL 5
TINKER AIR FORCE BASE IRP
CONTAMINANT SUMMARY

The table given below is a list of the number of occurrences per number of wells sampled and the maximum concentration encountered. The trapped water is in the trenches only and not the perched water table. The solid waste samples were samples obtained from actual waste in the trenches. The seep samples were obtained from a seep exiting the east side of the landfill near the landfill. As an example in the trapped water two holes were sampled and toluene was encountered in both with the max concentration being 230 ppb.

Table 6.1
Trapped Zone and Solid Waste Contaminant Occurrences

Organics

<u>Compound</u>	<u>Number of # Occurrences/# Samples</u>			<u>Max Concentrations</u>		
	Trapped Water	Solid Waste	Seep	Trapped Water (ug/l)	Solid Waste (ug/kg)	Seep (ug/kg)
2-Butanone	2/2	4/4	1/1	610	1150	16000
Toluene	2/2	3/4	1/1	230	250	42
Acetone	1/2	4/4	1/1	440	4500	24000
4-Methyl-2-Pentanone	1/2		1/1	630		7700
Ethylbenzene	1/2	1/4		340	180	
Xylenes	1/2	3/4		860	890	
Phenol	1/2	1/4	1/1	410	62000	1500
2-Methylphenol	1/2			180		
4-Methylphenol	1/2	1/4	1/1	120	3600	2600
Methylene Chloride		1/4	1/1		91	38
2-Chloroethylvinylether			1/1			220
2-Hexanone			1/1			210

Metals

<u>Compound</u>	<u>Number of # Occurrences/# Samples</u>			<u>Max Concentrations</u>			<u>Background Soil (ug/kg)</u>
	Trapped Water	Solid Waste	Seep	Water (ug/l)	Trapped Waste (ug/kg)	Solid Seep (ug/kg)	
Silver			1/1			700	560
Arsenic			1/1			2600	1100
Mercury		2/4	1/1		460000	420000	220000
Cadmium	2/2	4/4	1/1	20	28000	3000	720
Chromium		3/4	1/1		350000	39000	23000
Lead	2/2	3/4	1/1	120	480000	34000	15000
Nickel			1/1			53000	21000
Selenium			1/1			200	10
Zinc			1/1			620000	25000

Table 6.2 consists of the number of occurrences per number of wells sampled for each of the listed contaminants and the maximum concentration encountered for the perched aquifer at the landfill. As an example, for lead 5 wells were sampled and lead was encountered in 2 wells with the max concentration of the 2 being 53 ppb.

Table 6.2
Perched Aquifer Contaminant Occurrences

Compound	No. of Occurrences/No. of Wells	Maximum Concentrations
		(ug/l)
Trichloroethene	4/5	38
Trans-1,2-Dichloroethene	3/5	720
Bis(2-ethylhexyl)Phthalate	1/5	29
Vinyl Chloride	1/5	200
Barium	3/5	3500
Cadmium	3/5	13
Lead	2/5	53
Chromium	1/5	250

Table 6.3 is the contaminant occurrences in the top of regional aquifer. This table is the same as the others listed but samples were obtained from approximately 90 to 110 feet below grade.

Table 6.3
Top of Regional Contaminant Occurrences

Compound	No. of Occurrences/# of Wells	Maximum
		Concentration (ug/l)
Trichloroethene	2/4	45
Trans-1,2-Dichloroethene	2/4	14
Vinyl Chloride	1/4	34
Bis(2-ethylhexyl)phthalate	1/4	17
Benzene	1/4	19
Di-n-octylphthalate	1/4	11
Barium	2/4	5600
Chromium	1/4	180
Lead	1/4	80

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Landfill 5

TABLE 6.4
LANDFILL 5

CONTAMINANT SUMMARY

	Groundwater Samples			Trapped Zone & Waste Samples		
	# Occurrences Perched	# Wells Regional	Max Conc(1) Regional	# Occurrences Trapped	# Wells Waste Seep	Max Conc(1) Waste Seep
Trichloroethene	4/5	2/4	38			
Trans 1,2 Dichloroethene	3/5	2/4	720	1/2	4/4	4500
Acetone						
Vinyl Chloride	1/5	1/4	200			
Benzene		1/4				
2-Butanone (MEK)			34	2/2	4/4	1100
4-Methyl-2-Pentanone			19	1/2	1/1	16000
Toluene				1/2	1/1	7700
Ethylbenzene				2/2	1/1	42
Xylenes				1/2	1/4	230
Phenol				1/2	3/4	180
2-Methylphenol				1/2	3/4	890
4-Methylphenol				1/2	1/4	62000
Methylene Chloride				1/2	1/1	1500
2-Chloroethylvinylether				1/2	1/4	180
2-Hexanone				1/2	1/1	120
Barium	3/5	2/4	3500		1/4	91
Cadmium	3/5		13			
Chromium	1/5	1/4	250	2/2	2/4	460000
Lead	2/5	1/4	53		4/4	28000
				2/2	3/4	350000
					3/4	480000
					1/1	34000

(1) Perched, regional, and trapped zone samples are liquid and reported in ug/l, waste and seep samples are solid samples, and are reported in ug/kg.

Metals concentrations in groundwater are only those above drinking water standards.

F. Landfill 6

Site Description: Landfill 6 covers approximately 20 acres and was in use from 1970 to 1979. It is about 1/2 mile east of Tinker Air Force Base on land leased from Oklahoma City. General refuse, small amounts of industrial waste and industrial wastewater treatment plant sludge were disposed of at the landfill.

Contaminant Summary: The table titled Landfill 6 Contaminant Summary is a list of the organic contaminants at landfill 6 shown as the number of occurrences per number of wells sampled and per waste samples obtained. The maximum concentration encountered is also given. Samples were taken from the perched aquifer and the regional aquifer as wells as solid waste samples from the trenches. As an example in the perched aquifer for toluene 10 wells were sampled and toluene was encountered in 7 of the wells with the maximum concentration of the 7 occurrences being 170 ppb. The next table listed as "grab samples" is the number of occurrences per number of holes sampled for borings completed through the trenches and into the base material beneath the trenches. These samples are water samples taken from the perched aquifer existing directly beneath the trenches. The third table shown is similar to the previous tables and is for the metals encountered at the site.

LANDFILL 6

CONTAMINANT SUMMARY

Compound	Groundwater Samples		Max Conc P / R	Waste Samples	
	# OC / # wells	Regional		#OC/#Sample	Max Conc
	Perched				
Toluene	7/10	1/5	170/17	12/19	9100
Acetone	6/10	1/5	1300/720	10/19	36000
Bis(2-Ethylhexyl)Phthalate	4/10	2/5	24000/46	5/19	75000
Trichloroethene	4/10	2/5	13/41	4/19	160
Benzene	4/10	2/5	94/62	1/19	7
1,1-Dichloroethane	5/10		37/		
4-Methyl Phenol	4/10		4000/	7/19	71
Methylene Chloride	4/10		180/		
Trans-1,2-Dichloroethene	4/10		23/		
2-Butanone	3/10		2200/	13/19	6300
Total Xylenes	3/10		45/	13/19	170000
2-Hexanone	2/10		2600/	9/19	450
Phenol	2/10		1100/	1/19	22000
1,2-Dichloropropane	2/10		180/	7/19	2700
4-Methyl 2-Butanone	2/10		83/		
Vinyl Chloride	2/10		37/		
Diethyl Phthalate	2/10		26/		
Chloroethane	2/10		18/	5/19	4800
Tetrachloroethene	2/10		14/		
2,4-Dimethylphenol	1/10	1/5	10/66		
Benzoic Acid	1/10		1000/		
2-Methyl Phenol	1/10		270/	4/19	340
Chlorobenzene	1/10		190/		
n-Nitrosodipropylamine	1/10		190/		
Di-D-Octyl Phthalate	1/10		17/		
Di-N-Butyl Phthalate	1/10		17/	7/19	1500
Ethylbenzene	1/10		14/		
1,2-Dichlorobenzene		1/5	/68		
1,4-Dichlorobenzene		1/5	/45		
Bis(2-chloroethyl)ether		1/5	/30		
Napthalene				1/19	31000
Carbon Disulfide				1/19	8
Styrene				1/19	82

All values in mmb.

Landfill 6

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LANDFILL 6 GRAB SAMPLES

Compound	# Occurrences per # Holes	Max Concentration ug/l
----------	------------------------------	------------------------------

Toluene	3/4	170
4-Methyl-2-Pentanone	2/4	83
4-Methylphenol	2/4	1700
Methylene chloride	2/4	180
Acetone	1/4	790
1,1-Dichloroethene	1/4	37
Trans-1,2-Dichloroethene	1/4	8
2- Butanone	1/4	2200
1,2-Dichloropropane	1/4	21
Trichloroethene	1/4	13
2-Hexanone	1/4	2600
Total Xylenes	1/4	24
2-Methylphenol	1/4	270
Phenol	1/4	110
n-Nitrosodipropylamine	1/4	190
bis(2-Ethylhexyl)phthalate	1/4	13

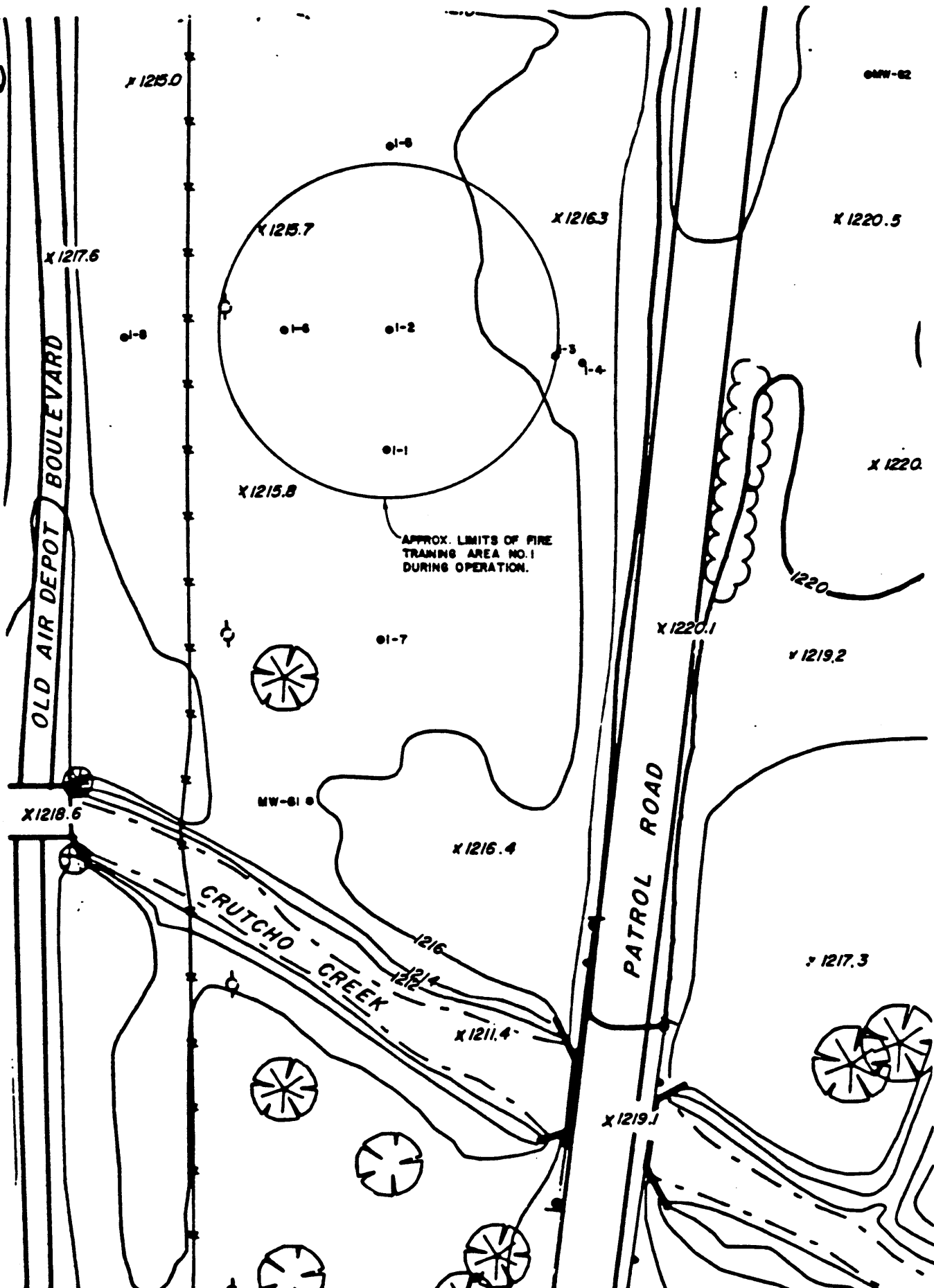
LANDFILL 6 METALS SUMMARY

Compound	# Occurrences/ # Samples				Max Concentration			
	Per.	Reg.	Grab	Solid Waste	Per. ug/l	Reg. ug/l	Grab ug/l	Waste mg/kg
Lead	10/10	5/5	4/4	19/19	100	280	93	570
Barium	7/10	4/5	3/4	19/19	10000	19000	8700	1000
Cadmium	7/10	3/5	4/4	19/19	23	15	10	34
Chromium	5/10	3/5	2/4	19/19	60	270	18	230
Arsenic	10/10	5/5	4/4	14/19	170	8.7	28	5.1
Selenium	3/10	2/5	0/4	7/19	2.2	1.8	0	0.9
Zinc	10/10	5/5	4/4	19/19	1200	220	1000	750
Nickel	10/10	5/5	4/4	19/19	1100	180	510	240

G. Fire Training Area #1

Site Description: This site is an unlined diked area where fuel oil was burned. It was used from 1950 to 1962.

Contaminant Summary: Phase 1 investigations at Fire Training Area #1 have been completed. Phase 2 investigations will soon be performed to establish the horizontal and vertical limits of site contamination. This will be done by augering in several locations around the site perimeter and performing soil gas analyses of the obtained soil samples on site. The soil gas analytical results will be confirmed by sending a portion of the samples to a laboratory for TOC analysis. The health and safety plan for this site needs to be updated to incorporate phase 1 findings and delineate any procedural changes necessary for phase 2 work. A site map showing boring locations and a contaminant summary from phase 1 investigations are attached to aid in this process.



04W-62

APPROX. LIMITS OF FIRE
TRAINING AREA NO. 1
DURING OPERATION.

OLD AIR DEPOT BOULEVARD

PATROL ROAD

CRUTCH CREEK



5-8

FTA #1

Fire Training Area #1 - Detected Non-Listed Organic Compounds

BORING OR WELL NUMBER	
1	2
SOIL (0 - 1')	SOIL (0 - 1')
2,3,5-trimethyl heptane (710)	N-methyl-methanamine (5)
unknowns (2,910)	unknowns (250,009)
SOIL (4 - 7')	SOIL (4 - 7')
3-methyl-octane (910)	unknowns (1,768)
unknowns (98,616)	SOIL (10 - 13')
SOIL (10 - 13')	2,2,3,4-tetramethyl-pentane (10)
6-methyl-undecane (840)	1,4-dimethyl-, trans-cyclooctane (4)
unknowns (5)	2,3,5-trimethyl heptane (770)
unknowns (5)	unknowns (7)
WATER	WATER
SOIL	
(ug/kg)	2-(2-ethoxyethoxy)-ethanol (12)
1,1,2-trichloro-1,1,2-trifluoro-ethane (14)	2-hydroxy-benzaldehyde (12)
1,1,2-trichloro-1,2,2-trifluoro-ethane (42)	1,2-dichloro-1,1,2-trifluoro-ethane (55)
3-methyl-pentane (14)	1,1,2-trichloro-1,2,2-trifluoro-ethane (490)
propanoic acid, 2-methyl, 1-(1,1-dimethyl) (10)	methyl-cyclopentane (17)
unknowns (24)	3-methyl-pentane (240)
WATER	2,6-dimethyl-nonane (110)
(ug/l)	unknowns (68)

615

Fire Training Area #1 - Detected Non-Listed Orgd

Compounds Cont'd

BORING OR WELL NUMBER

3

SOIL (0 - 1')

hexenedioic acid, diethyl ester (47,000)
1,2-benzenedicarboxylic acid, diisocetyl (4,400)
unknowns (25,354)

SOIL (4 - 7')

1,2-benzenedicarboxylic acid, bis(4-methyl-5-oxo)
hexenedioic acid, diethyl ester (4,400)
1,2-benzenedicarboxylic acid, diethyl ester (170)
1,2-benzenedicarboxylic acid, isodecyl ester (250)
unknowns (4,124)

SOIL (7 - 10')

3-methyl-hexane (36)
2,5,6-trimethyl-octane (520)
2,5-dimethyl-hexane (35)
2,5-dimethyl-hexane (62)
1,1,3-trimethyl-cyclohexane (32)
2,2,4-trimethyl-heptane (750)
2-methyl-propyl-cyclopentane (1,000)
2,3,7-trimethyl-octane (810)
2,3-dimethyl-octane (1,200)
8-methyl-undecane (890)
2,5,6-trimethyl-octane (1,800)
2,2,3,4-tetramethyl-pentane (860)
3-ethyl-5-methyl-heptane (2,000)
butyl-cyclohexane (710)
3,7-dimethyl-nonane (790)
2,6,8-trimethyl-decane (1,200)
2,5,9-trimethyl-decane (1,300)
2,3,7-trimethyl-decane (670)
1,2-benzenedicarboxylic acid, diisocetyl (2,700)
unknowns (5,817)

SOIL (10 - 13')

2,4-dimethyl-pentane (14)
3-methyl-hexane (25)
2,2,3,4-tetramethyl-pentane (120)
2,3-dimethyl-hexane (55)
2,5-dimethyl-hexane (13)
1,1,3-trimethyl-cyclohexane (7)
2,2,5-trimethyl-cyclohexane (33)

hexenedioic acid, mono (2-ethyl-hexyl) ester (230)
unknowns (466)

WATER

cyclohexanone (570)
2,3-dimethyl-octane (24)
2,5,6-trimethyl-octane (36)
1-methyl-3-(2-methyl-propyl) cyclopentane (16)
2,6-dimethyl-nonane (39)
undecyl-cyclohexane (15)
2-ethyl-1-decanol (16)
6-methyl-dodecane (33)
2,3,7-trimethyl-octane (33)
3-methyl-pentane (34)
3-methyl-hexane (87)
2,2,3,4-tetramethyl-pentane (3,900)
3-methyl-hexanal (2,100)
o-decyl-hydroxylamine (920)
2,3-dimethyl-hexane (370)
2,5-dimethyl-hexane (450)
2,2,5-trimethyl-hexane (1,300)
2,5,6-trimethyl-decane (600)
2,7,10-trimethyl-dodecane (22)
2,6-dimethyl-heptadecane (22)
unknowns (195)

4

SOIL (0 - 1')

5-methyl-5-hexen-2-one (380)
5-methyl-2-hexanone (7,900)
2,4-dimethyl-2-pentanone (59,000)
2,3,4-trimethyl-hexane (2,100)
2,3,6-trimethyl-heptane (3,300)
unknowns (8,020)

SOIL (1 - 4')

5-methyl-2-hexanone (4,900)
2,4-dimethyl-2-pentanone (61,000)
2,3,4-trimethyl-hexane (1,800)
1-cyclohexyl-2-propanone (170)
2,3,6-trimethyl-heptane (2,600)
unknowns (2,816)

SOIL (4 - 7')

5-methyl-2-hexanone (2,800)
2,4-dimethyl-2-pentanone (51,000)
2,3,4-trimethyl-hexane (1,200)
1-cyclohexyl-2-propanone (130)
2,3,6-trimethyl-heptane (2,600)
unknowns (1,900)

SOIL (7 - 10')

5-methyl-2-hexanone (3,800)
2,3,4-trimethyl-hexane (1,700)
2,3,6-trimethyl-heptane (2,700)
2,4,6-trimethyl-octane (210)
unknowns (74,930)

SOIL (10 - 13')

5-methyl-2-hexanone (4,200)
1-methyl-ethyl-benzene (330)
2,3,4-trimethyl-hexane (1,800)
2,3,6-trimethyl-heptane (2,600)
hexenedioic acid, mono (2-ethyl-hexyl) ester (1,100)
unknowns (64,200)

SOIL (13 - 16')

5-methyl-2-hexanone (3,500)
2,3,4-trimethyl-hexane (2,000)
2,3,6-trimethyl-heptane (2,900)
unknown (490)

SOIL (16 - 22')

5-methyl-2-hexanone (4,000)
2,3,4-trimethyl-hexane (1,500)
2,3,6-trimethyl-heptane (2,200)
unknowns (1,620)

SOIL (22 - 27')

5-methyl-2-hexanone (3,500)
2,3,4-trimethyl-hexane (1,600)
2,3,6-trimethyl-heptane (2,400)
unknowns (720)

Fire Training Area #1 - Detected Non-Listed Organic Compounds Cont'd

BORING OR WELL NUMBER	
5	6
SOIL (0 - 1')	SOIL (0 - 1')
acetic acid, 1-methylethyl ester (4,300)	5-methyl-5-hexen-2-one (530)
3,4-dimethyl-octane (180)	1-iodo-dodecane (1,200)
5-methyl-2-hexanone (2,400)	tricarbohydln-(phenyl-2-pyridinyl)-iron (3,200)
2,3,4-trimethyl-hexane (1,200)	unknowns (19,646)
2,3,6-trimethyl-heptane (1,800)	SOIL (1 - 4')
2,4-pentanedione (390)	unknowns (13,670)
5-methyl-5-hexen-2-one (330)	SOIL (4 - 7')
unknowns (68,251)	
SOIL (1 - 4')	
5-methyl-2-hexanone (1,700)	5-methyl-2-hexanone (2,100)
3,3-dimethyl-hexane (670)	2,3,4-trimethyl-hexane (700)
2,3,6-trimethyl-heptane (1,100)	2,3,6-trimethyl-heptane (1,200)
5-methyl-5-hexen-2-one (180)	unknowns (59,330)
unknowns (6,070)	SOIL (7 - 10')
SOIL (4 - 7')	
1-cyclohexyl-2-propanone (170)	1,1,2-trichloro-1,2,2-trifluoro-ethane (44)
unknowns (1,320)	2,2,3,4-tetramethyl-pentane (12)
SOIL (7 - 10')	unknowns (1,300)
	SOIL (10 - 13')
	unknowns (1,100)
SOIL	SOIL (13 - 16')
1,1,2-trichloro-1,2,2-trifluoro-ethane (84)	unknowns (520)
2,2,3,4-tetramethyl-pentane (27)	SOIL (16 - 22')
1,1,3-trimethyl-cyclohexane (15)	
2,2,5-trimethyl hexane (9)	5-methyl-2-hexanone (2,200)
1,2,3-trimethyl-cyclohexane (1-alpha) (4)	2,3,4-trimethyl-hexane (680)
1-ethyl-2-methyl cyclohexane, cis (9)	2,3,6-trimethyl-heptane (1,300)
1,1,3,5-tetramethyl cyclohexane, trans (15)	5,5-dimethyl-2(5h)-furanone (190)
unknowns (1,309)	tetrateetracontane (170)
SOIL (10 - 13')	unknowns (64,440)
2,2,3,4-tetramethyl-pentane (4)	SOIL (22 - 28')
unknowns (1,218)	
SOIL (13 - 16')	
1-cyclohexyl-2-propanone (220)	5-methyl-2-hexanone (2,100)
unknowns (1,110)	4-methyl-octane (810)
SOIL (16 - 22')	2,3,5-trimethyl-heptane (1,300)
2-[2-(2-butoxyethoxy)ethoxy]-ethanol (270)	1,3,6-trioxane (5)
unknowns (600)	unknowns (53,143)
SOIL (22 - 28')	
unknowns (590)	

Fire Training Area #1 - Detected Non-Listed Organic Compounds Cont'd

BORING OR WELL NUMBER		
7		
SOIL (0 - 1')		SOIL (0 - 1')
5-methyl-2-hexanone (3,000)	5-methyl-2-hexanone (2,800)	
2,3,4-trimethyl-hexane (1,300)	2,3,6-trimethyl-heptane (1,200)	
2,3,6-trimethyl-heptane (1,900)	5,5-dimethyl-2(5h)-furanone (410)	
unknowns (74,900)	N,N-diethyl-3-methyl-benzamide (220)	
unknowns (7,900)	unknowns (7,170)	
SOIL (1 - 7')	SOIL (1 - 7')	
5-methyl-2-hexanone (3,000)	5-methyl-2-hexanone (2,600)	
2,3,4-trimethyl-hexane (1,200)	2,3,4-trimethyl-hexane (1,100)	
2,3,6-trimethyl-heptane (1,800)	2,3,6-trimethyl-heptane (1,500)	
5-methyl-5-hexen-2-one (700)	unknowns (1,300)	
unknowns (1,460)		
SOIL (7 - 13')	SOIL (7 - 13')	
5-methyl-2-hexanone (2,900)	5-methyl-2-hexanone (2,800)	
2,3,4-trimethyl-hexane (1,200)	4-methyl-octane (1,100)	
2,3,5-trimethyl-heptane (1,700)	3-methyl-octane (1,600)	
hexanedioic acid, mono(2-ethyl-hexyl) ester (1,200)	unknowns (2,130)	
unknowns (3,820)		
SOIL (13 - 19')	SOIL (13 - 19')	
5-methyl-2-hexanone (2,800)	4-methyl-octane (1,100)	
4-methyl-octane (1,100)	2,3,6-trimethyl-heptane (1,600)	
2,3,6-trimethyl-heptane (1,600)	unknown (820)	
unknowns (870)		
SOIL (19 - 25')	SOIL (19 - 25')	
5-methyl-2-hexanone (2,900)	4-methyl-octane (1,100)	
2,3,4-trimethyl-hexane (1,300)	2,3,6-trimethyl-heptane (1,600)	
2,3,5-trimethyl-heptane (1,800)	5,5-dimethyl-2(5h)-furanone (230)	
5,5-dimethyl-2(5h)-furanone (430)	unknowns (1,490)	
unknowns (1,300)		

Fire Training Area #1 - Detected Non-Listed Organic Compounds Cont'd

BORING OR WELL NUMBER	
MM 61	MM 62
<p>C O N T A M I N A N T</p> <p>WATER</p> <p>1,1,2-trichloro-1,2,2-trifluoro-ethane (110) 5-methyl-2-hexanone (18) 2-methyl-1-(1,1-dimethyl) propanoic acid (31) unknown (9)</p>	<p>WATER</p> <p>1,2-dichloro-1,1,2-trifluoro-ethane (19) 1,1,2-trichloro-1,2,2-trifluoro-ethane (2,200) 5-methyl-2-hexanone (20) prometon (acn) (9) 2-methyl-1-(1,1-dimethyl) propanoic acid (15) unknown (14)</p>
<p>organics (ug/l) metals (mg/l) TOC (mg/l)</p>	

Fire Training Area # 1 - Detected Listed Organics, Metals, and Indicator Parameters

BORING OR WELL NUMBER		
1	2	
SOIL (0 - 1')	SOIL (0 - 1')	
methylene chloride (19)	cadmium (17)	
bis (2-ethylhexyl) phthalate (1,900)	lead (170)	
TOC (2,800)	methylene chloride (11)	
	TOC (26,000)	
SOIL (4 - 7')	SOIL (4 - 7')	
	methylene chloride (14)	
	TOC (3,800)	
	SOIL (10 - 13')	
	methylene chloride (20)	
	acetone (18)	
	bis (2-ethylhexyl) phthalate (<410)	
	TOC (1,300)	
SOIL (10 - 13')		
methylene chloride (16)		
bis (2-ethylhexyl) phthalate (410)		
TOC (500)		
WATER		
vinyl chloride (<10)		
trans-1,2-dichloroethene (15)		
tetrahydrofuran (190)		
TOC (15.6)		
Ph (6.4)		
conductivity (580 uMhos/cm)		
organics (ug/l)		
metals (mg/l)		
TOC (mg/kg)		
WATER		
vinyl chloride (17)		
trans-1,2-dichloroethene (89)		
2-butanone (18)		
trichloroethene (17)		
1,1,2-trichloroethane (13)		
benzene (7)		
fluoranthene (<10)		
pyrene (<10)		
tetrahydrofuran (76)		
TOC (12.3)		
Ph (6.6)		
conductivity (780 uMhos/cm)		

Note: Values Listed as <X indicate that the compound was present but below the detection limit X.

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ETA # 1

Fire Training Area # 1 - Detected Listed Organics, Metals, and Indicator Parameters Cont'd

BORING OR WELL NUMBER		
3	4	
SOIL (0 - 1')	SOIL (0 - 1')	
methylene chloride (21)	methylene chloride (7)	
acetone (13)	bis (2-ethylhexyl) phthalate (770)	
bis (2-ethylhexyl) phthalate (5,200)	trichlorofluoro-methane (8)	
tetrahydrofuran (4)	SOIL (1 - 4')	
TOC (12,000)		
SOIL (4 - 7')	methylene chloride (<6)	
methylene chloride (29)	acetone (<12)	
acetone (28)	2-hexanone (<12)	
bis (2-ethylhexyl) phthalate (5,900)	bis (2-ethylhexyl) phthalate (1,700)	
tetrahydrofuran (4)	SOIL (4 - 7')	
TOC (4,200)		
SOIL (7 - 10')	methylene chloride (9)	
methylene chloride (130)	acetone (35)	
tetrahydrofuran (190)	bis (2-ethylhexyl) phthalate (2,300)	
TOC (1,500)	tetrahydrofuran (6)	
SOIL (10 - 13')	SOIL (7 - 10')	
methylene chloride (28)	methylene chloride (<6)	
acetone (<12)	bis (2-ethylhexyl) phthalate (7,300)	
bis (2-ethylhexyl) phthalate (<170)	SOIL (10 - 13')	
TOC (2,700)		
SOIL	methylene chloride (15)	
WATER	acetone (190)	
2-butanone (6,450)	bis (2-ethylhexyl) phthalate (<420)	
benzene (9)	SOIL (13 - 16')	
4-methyl-2-pentanone (<10)	methylene chloride (12)	
chlorobenzene (21)	acetone (46)	
tetrahydrofuran (720)	trichlorofluoro-methane (9)	
TOC (2,700)	tetrahydrofuran (6)	
SOIL (16 - 22')	SOIL (16 - 22')	
methylene chloride (13)		
acetone (94)	methylene chloride (13)	
bis (2-ethylhexyl) phthalate (560)	acetone (<12)	
tetrahydrofuran (16)	bis (2-ethylhexyl) phthalate (560)	
SOIL (22 - 27')	tetrahydrofuran (16)	
methylene chloride (<6)	SOIL (22 - 27')	
bis (2-ethylhexyl) phthalate (<380)		
tetrahydrofuran (17)	methylene chloride (<6)	
	bis (2-ethylhexyl) phthalate (<380)	
	tetrahydrofuran (17)	

Note: Values listed as <X indicate that the compound was present but below the detection limit X.

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compound was present but below the detection limit X.

Fire Training Area # 1 - Detected Listed Organics, Metals, and Indicator Parameters Cont'd

BORING OR WELL NUMBER	
7	8
SOIL (0 - 1')	SOIL (0 - 1')
bis (2-ethylhexyl)phthalate (2,200)	butyl benzyl phthalate (<410)
SOIL (1 - 7')	bis (2-ethylhexyl)phthalate (11,000)
bis (2-ethylhexyl)phthalate (3,600)	SOIL (1 - 7')
SOIL (7 - 13')	bis (2-ethylhexyl)phthalate (1,600)
bis (2-ethylhexyl)phthalate (440)	SOIL (7 - 13')
SOIL (13 - 19')	diethyl phthalate (<450)
bis (2-ethylhexyl)phthalate (<400)	bis (2-ethylhexyl)phthalate (<450)
SOIL (19 - 25')	SOIL (13 - 19')
bis (2-ethylhexyl)phthalate (1,300)	bis (2-ethylhexyl)phthalate (<420)
SOIL (19 - 25')	SOIL (19 - 25')
bis (2-ethylhexyl)phthalate (930)	

Note: Values Listed as <X indicate that the compo und was present but below the detection limit X.

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Fire Training Area # 1 - Detected Listed Organics, Metals, and Indicator Parameters Cont'd

BORING OR WELL NUMBER	
MM 61	MM 62
<p>WATER</p> <p>barium (3,200) iron (54,000) manganese (1,800) vinyl chloride (71) trans-1,2-dichloroethene (540) 1,1,1-trichloroethane (<5) trichloroethene (32) TOC (8.9)</p>	<p>WATER</p> <p>barium (1,100) iron (27,000) manganese (900) trichloroethene (17) tetrachloroethene (<5) TOC (20)</p>
<p>COD</p> <p>organics (ug/l) metals (mg/l) TOC (mg/l)</p>	

Note: Values Listed as <X indicate that the compound was present but below the detection limit X.

81-5

H. Fire Training Area #4

Site Descriptions: According to a map provided by TAFB personnel, Fire Training Area #4 is located southeast of the ammunition depot near the north edge of pistol pond as shown on enclosure 1. This site is presently a grassy area with no visible signs of its past use as a fire training area. No documentation of the exact location or period of operation of this site is available at the present time.

Contaminant Summary: No information is available at this time.

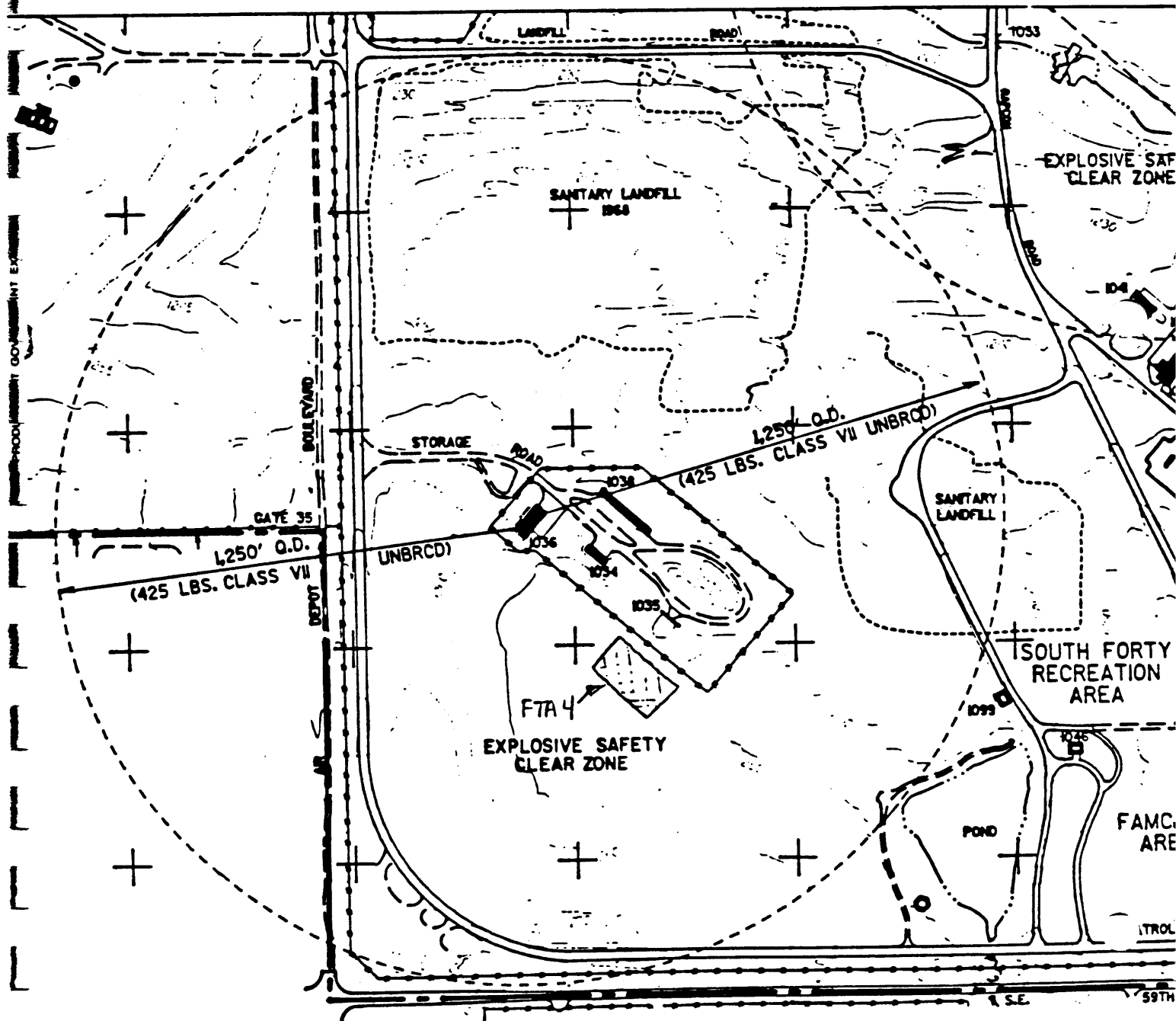
22

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I. Soldier Creek

Site Description: Soldier Creek on Tinker Air Force Base has two arms. The main streambed, East Soldier Creek, begins on the southwestern portion of the base as a storm drain which collects runoff from roadways, parking areas, and buildings. Water from the storm drain emerges from under SE 44th Street just north of building 3705 and becomes a surface flowing stream. From this point to its exit from the base at approximately SE 36th Street and Douglas Boulevard, East Soldier Creek receives water from several storm drains from the building 3001 area, and NPDES permitted discharges from the industrial waste and sewage treatment plants. From SE 44th Street to the entrance road from gate 20, the streambed is densely wooded with thick underbrush. From this point to Douglas Boulevard, the dense vegetation was removed during channelization work done for the treatment plants and during the 1985 cleanup project. Off base, East Soldier Creek flows in its natural streambed except for road crossing until it flows into Crutcho Creek. West Soldier Creek begins as a man-made channel built to collect runoff from the runway system. This arm also collects several NPDES permitted discharges from industrial operations in and around Building 3001. The storm drain discharges into an open channel northeast of gate No. 7 which flows above ground until crossing under I-40, and eventually merges with East Soldier Creek.

Contaminant Summary: Samples taken from East and West Soldier Creeks during the Phase 2 Stage 2 Confirmation/Quantification portion of the IRP contained elevated levels of cadmium, lead, zinc, chromium, and nickel. Analysis of soil samples taken after the 1985 cleanup project indicated that on base sediments around East Soldier Creek were still contaminated with lead (30 -500 mg/kg), chromium (300-1050 mg/kg), and cadmium (100 -300 mg/kg). In addition, the OWRB reports that water and sediment samples taken from the eastern arm and beyond the confluence of the east and west arms during a recent study were acutely toxic to flathead minnows as far as SE 15th Street, and chronically toxic at least as far as J. Barnes Regional Park on Reno Avenue. Thus, the problem is existing and ongoing contamination of surface water, stream sediments, and possible underlying soils and groundwater.

J. Crutcho Creek

Site Description: Crutcho Creek runs north and northeast through the eastern half of Tinker Air Force Base.

Contaminant Summary: An excerpt from the Phase II, Stage 2, IRP report prepared by Radian Corporation is reprinted on the following pages. The excerpt describes results of a sediment sampling program conducted in 1984.

4.2.4 Sediment Sampling

Sediment samples collected at Tinker AFB (Figure 4-13) were submitted for the analyses shown on Table 1-2. Results of analyses are shown on Table 4-16. The analytical data were evaluated for internal consistency and the existence of trends (systematic downstream changes in composition), rather than comparison to an outside set of standards or criteria. Where the concentration of a given species is noted to be higher or to "stand out" in the analytical results, it is discussed below. Results of sampling along each Base stream are presented below.

Crutcho Creek

Crutcho Creek drains the western portion of Tinker AFB and also receives some discharge from areas south of the installation. The creek drains a relatively large portion of the Base which includes several landfills and fire training areas. The Base housing area and golf course are also drained by this creek.

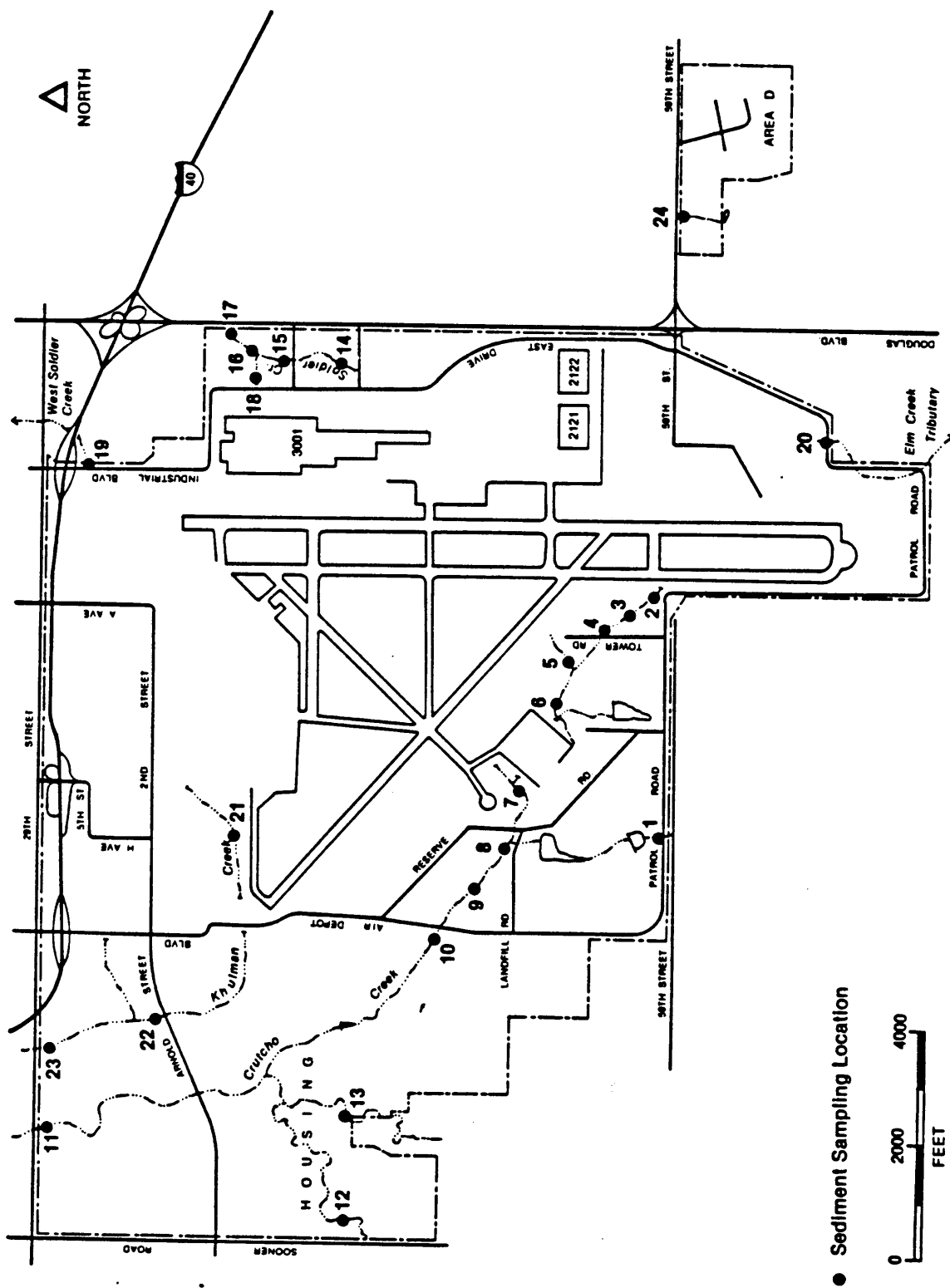


Figure 4-13. Locations of Stream Sediment Sampling Stations, Tinker AFB
IRP Phase II Stage 2.

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TABLE 4-16. RESULTS OF STREAM SEDIMENT ANALYSIS, TINKER AFB IRP PHASE II STAGE 2

Sampling Station (see Figure 4-13)	1	2	3	4	4	5	6	7	8	9	9
Sample Number	T-SED-01	T-SED-02	T-SED-03	T-SED-04	T-SED-05 (duplicate)	T-SED-25	T-SED-24	T-SED-23 (follow-up sample)	T-SED-20 (follow-up sample)	T-SED-21	T-SED-22
Laboratory Batch Number	84-06-166	84-06-166	84-06-166	84-06-166	84-06-166	84-06-206	84-06-206	84-06-113	84-06-113	84-06-206	84-06-206
Date of Sample	6/19/84	6/19/84	6/19/84	6/19/84	6/19/84	6/21/84	6/21/84	7/19/84	7/19/84	6/21/84	6/21/84
Parameter ^{1,2}											
Silver	<1.8	<1.7	<2	<2	<2	<2	<2	<1	<1	<2	<2
Arsenic	0.35	0.41	0.31	0.36	0.52	0.64	2.3	<0.1	<0.1	1.5	2.7
Barium	480	240	290	410	450	310	480	610	230	390	370
Cadmium	<0.50	<41	4.7	2.2	<0.63	2.4	2.7	0.97	2.4	3.0	1.5
Total Cyanide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.1	<0.1	<0.2	<0.2
Chromium	11	55	320	43	48	51	150	30	38	80	71
Copper	2.8	5.7	24	3.6	5.9	8.3	13	8.2	15	12	11
Fluoride	0.5	0.33	0.33	0.23	0.30	0.54	0.38	33	8	0.23	0.31
Mercury	0.049	0.061	0.051	0.060	0.038	0.094	0.090	0.23	0.37	0.06	0.12
Manganese	900	920	270	410	630	310	720	520	470	790	1000
Nickel	9.7	7.8	9.5	15	13	12	14	8.5	7.0	10	8.3
Nitrate	1.4	<6	<6	<6	<6	1.4	<1	3.2	1.9	<1	0.46
Lead	10	0.36	23	14	21	11	45	8.7	55.8	49	23
PCBs ³	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.025	0.036	<0.5	<0.5
Phenolics	<0.1	0.18	0.11	0.05	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
pH	7.10	6.90	7.10	6.75	6.71	6.39	7.34	7.30	7.30	7.26	6.34
Selenium	0.55	0.61	0.39	0.48	0.53	0.71	0.63	<0.02	<0.02	0.65	0.48
Total Organic Carbon	0.52	0.38	0.63	1.03	0.42	1.32	0.44	0.30	1.30	1.48	1.01
Zinc	18	24	54	24	24	22	42	20	53	33	31

(Continued)

TABLE 4-16. (Continued)

Sampling Station (see Figure 4-13)	10	11	12	13	14	15	15	16	17	18	19
Sample Number	T-SED-19	T-SED-26	T-SED-07	T-SED-08	T-SED-15	T-SED-13	T-SED-18 (duplicate)	T-SED-14	T-SED-11	T-SED-12	T-SED-16
Laboratory Batch Number	84-06-206	84-06-206	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190
Date of Sample	6/21/84	6/21/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84
Parameter ^{1,2}											
Silver	<2	<2	<2	<2	<2.8	<2	<2	<2	<2	<2	<2
Arsenic	0.81	1.6	1.9	2.1	0.28	1.6	0.51	0.54	0.66	0.31	0.62
Barium	330	320	430	480	330	220	200	320	170	410	220
Cadmium	3.9	1.8	1.1	0.36	30	1.3	4.9	0.70	50	12	11
Total Cyanide	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	68	13	37	12	140	190	120	27	1300	130	300
Copper	12	4.3	5.1	4.4	52	230	54	3.8	45	160	69
Fluoride	0.2	<.1	0.22	0.20	0.16	0.20	0.31	0.37	0.31	0.23	0.33
Mercury	0.45	0.036	0.038	0.048	1.6	1.0	0.33	0.034	0.35	0.10	0.14
Manganese	250	500	1000	940	140	250	250	530	790	330	170
Nickel	7.4	3.7	9.5	9.4	19	43	12	6.4	230	83	170
Nitrate	2.8	<.1	<.6	<.6	<.6	<.6	<.6	<.6	<.6	<.6	<.6
Lead	40	17	27	15	530	140	97	7.1	46	700	52
PCBs ³	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.20
Phenolics	<0.1	<0.1	0.13	0.10	0.06	0.10	0.10	0.11	0.04	0.09	0.14
pH	7.62	7.68	7.19	7.32	7.01	7.19	7.15	7.25	7.73	7.54	7.16
Selenium	0.67	0.63	0.93	1.0	0.21	0.93	0.31	0.21	0.28	0.12	0.32
Total Organic Carbon	0.81	0.25	0.41	0.59	3.80	1.32	0.65	0.25	0.87	0.43	1.68
Zinc	43	11	32	17	160	210	77	16	83	88	60

(Continued)

Samples were collected from 13 stations along Crutch Creek and its tributaries. In a downstream direction, the sampling stations along Crutch Creek and its tributaries are Stations 2, 3, 4, 5, 6, 7, 1, 8, 9, 10, 13, 12 and 11, as shown in Figure 4-13.

Station 2 lies just upstream of landfill No. 5 along Crutch Creek. This station receives runoff from the southern part of the North-South runway. Chemical parameters for this sampling station appear to be indicative of natural conditions although phenolics were detected at a concentration of 0.18 ug/g. It should be noted that low concentrations of phenolics were detected in 16 of the 27 samples collected during this study.

Sediment sampling stations 3 and 4 are downstream of Station 2, adjacent to Landfill No. 5. No elevated concentrations of industrial contaminants were found at this station. A duplicate sediment sample was collected for Station 4 as a field quality control sample. The analysis for the Station 4 field duplicate is comparable to that of the station sample.

Downstream, to the west of Tower Road and downstream of Landfill No. 5, are Stations 5, 6, and 7. During sampling operations, a phenolic odor was noted at Station 7, but analysis for phenolics at Station 7 show them to be below detection limits.

Station 8 lies downstream of Station 7, below the confluence of Crutch Creek and a tributary. Station 1 lies on the tributary as it enters the installation from the area south of the Base. Of the two stations, only Station 8 showed an elevated concentration of a potential industrial contaminant, Fluoride, which was detected at 8 ug/g.

Station 9 lies downstream of Station 8 and Landfills 2, 3, and 4. Station 10 is located just downstream of Patrol Road, Station 9 and Landfills 1 through 4. Both stations showed no elevated concentrations of industrial contaminants. A duplicate sample was collected at Station 9 as a field quality control sample. Results for the quality control sample collected at Station 9 are consistent with the station sample.

RADIAN
CORPORATION

Stations 12 and 13 lie near the southwestern corner of the installation along two tributaries to Crutch Creek. These stations are located close to the installation boundary within the Base housing area. Analysis for samples collected from these stations do not indicate the presence of contamination.

Station 11 is located near the northern installation boundary where the creek leaves the Base. There is no direct indication of industrial contamination from the analysis of sediments at this station.

K. Khulman Creek

Site Description: Khulman Creek runs north and west through the north-central part of Tinker AFB.

Contaminant Summary: An excerpt from the Phase II, Stage 2 IRP report prepared by Radian Corporation is reprinted on the following pages. The excerpt describes results of a sediment program conducted in 1984.

4.2.4 Sediment Sampling

Sediment samples collected at Tinker AFB (Figure 4-13) were submitted for the analyses shown on Table 1-2. Results of analyses are shown on Table 4-16. The analytical data were evaluated for internal consistency and the existence of trends (systematic downstream changes in composition), rather than comparison to an outside set of standards or criteria. Where the concentration of a given species is noted to be higher or to "stand out" in the analytical results, it is discussed below. Results of sampling along each Base stream are presented below.

Khulman Creek

Khulman Creek drains the north-central portion of the Base. The creek receives runoff from the area north of the airfield which is predominantly office and warehouse buildings.

Samples were collected from three stations along Khulman Creek. In a downstream direction, these stations are Station 21, 22, and 23 as shown in Figure 4-13. Analysis for Station 22 show manganese at a concentration of 4700 ug/g. No evidence of industrial contamination was found at Stations 21 and 23.

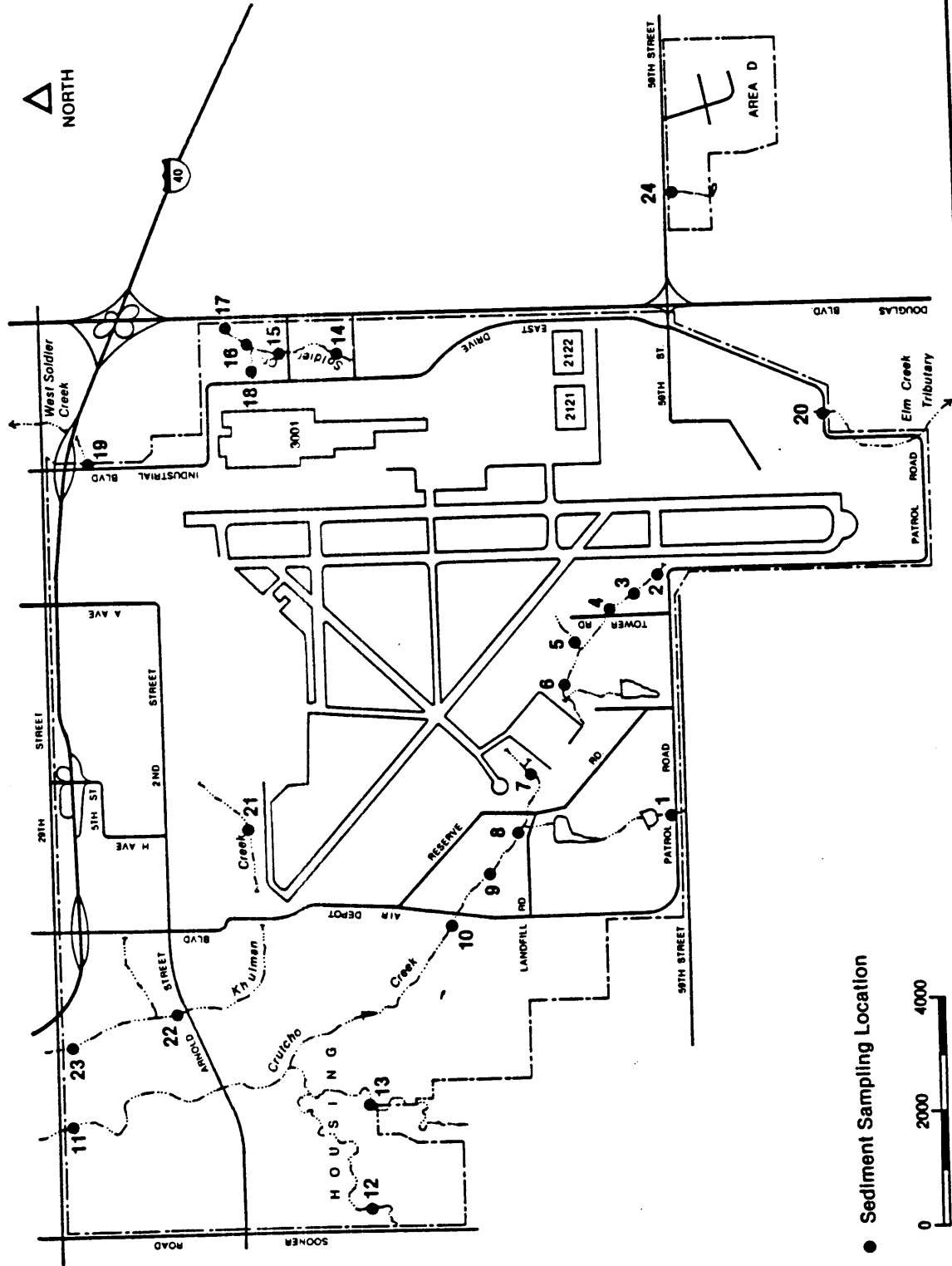


Figure 4-13. Locations of Stream Sediment Sampling Stations, Tinker AFB
IRP Phase II Stage 2.

C1142

4-45

4-53

TABLE 4-16. (Continued)

1 In addition to these parameters, analyses for RCRA pesticides and herbicides were performed. Results were everywhere less than detection limits noted.

RCRA Herbicides
2,4-D (<0.2 µg/g)
2,4,5-TP (Silvex) (<0.2 µg/g)

RCRA Pesticides
Lindane (<0.002 µg/g)
Endrin (<0.002 µg/g)
Methoxychlor (<0.002 µg/g)
Toxaphene (<0.02 µg/g)

2 Expressed in µg/g unless specified otherwise.

3 In contrast to the information supplied in Appendix M, the actual detection limit for PCBs is 0.5 µg/g (0.025 µg/g for Batch 84-07-113).

Sampling Station (see Figure 4-13)	20	21	22	23	24
	T-SED-06	T-SED-10	T-SED-09	T-SED-27	T-SED-28 (follow-up sample)
Laboratory Batch Number	84-06-166	84-06-190	84-06-190	84-06-206	84-06-113
Date of Sample	6/19/84	6/20/84	6/20/84	6/21/84	7/19/84
Parameter ^{1,2}					
Silver	<2	<2	<2	<2	<1
Arsenic	0.49	0.91	3.5	1.0	<1
Barium	520	230	380	240	110
Cadmium	2.4	0.54	1.6	2.1	0.83
Total Cyanide	<.01	<.01	<.01	<.02	<.01
Chromium	5100	80	33	35	12
Copper	23	25	10	0.12	5.0
Fluoride	0.62	0.31	0.51	<0.01	2.5
Mercury	0.049	0.33	0.19	0.30	0.25
Manganese	710	180	4700	290	250
Nickel	47	12	11	5.9	5.9
Nitrate	2.14	<.6	<.6	1.9	3.2
Lead	100	39	44	64	8.1
PCBs ³	<0.5	<0.5	<0.5	<0.5	<0.025
Phenolics	0.09	0.11	0.08	<.01	<.01
pH	8.53	7.03	7.24	7.16	6.37
Selenium	0.61	0.32	1.8	0.43	<.002
Total Organic Carbon	2.28	0.41	0.54	0.85	0.85
Zinc	68	66	35	49	8.3

(Continued)

4-48
4-54

L. Fuel Contaminated Sites near Building 201 & 214

Site Descriptions and Contaminant Summaries: Building 214 lies between A and B Avenues and south of 2nd Street. Building 201 lies between C and D Avenues and north 9of 1st Street.

a. Building 201. There are three separate areas affected around Building 201. They are identified as area "BB" on the west, area "BR" on the south and area "BC" on the northeast. Area BB has an abandoned diesel tank and has minor amounts of hydrocarbon contamination in the soil at a depth of 8 feet. Area "BR" has an abandoned tank of unknown contents and has both hydrocarbon and halocarbon contamination (3880 ppm hydrocarbons, and .3 ppm halocarbons). Area "BC" had minor amounts of halocarbon contamination with a high of 5.2 ppm halocarbons and is the site of an abandoned waste solvent tank. Trichloroethylene and chloroform have been identified as two of the contaminants.

b. Building 214. The area west of the south end of building 214 is the site of an abandoned tank of unknown contents. Benzene, toluene, xylenes, vinyl chloride, 1, 1-Dichloroethene. 1-Dichloroethene, Trans-1,2 Dichloroethene 1, 1, 1 Trichloroethane, Trichloroethene, and Ethylbenzene were detected in a groundwater sample. The concentration of Trans-1, 2 Dichloroethene was 175910 ppb. An oily film was noted on the groundwater.

M. Industrial Waste Pit No. 2

Site Description: Prior to the establishment in 1963 of an industrial wastewater collection and treatment system, some of the industrial wastes from Tinker AFB were disposed of in large, open pits. In 1958, IWP-2 was constructed on a hill between Patrol Road and the airfield runway. The pit received hazardous wastes such as waste oils, cyanides, chromates, phenols, solvents, and waste acids and alkalies. No information is available on the construction details or exact location of the pit. The pit was filled and graded in 1965.

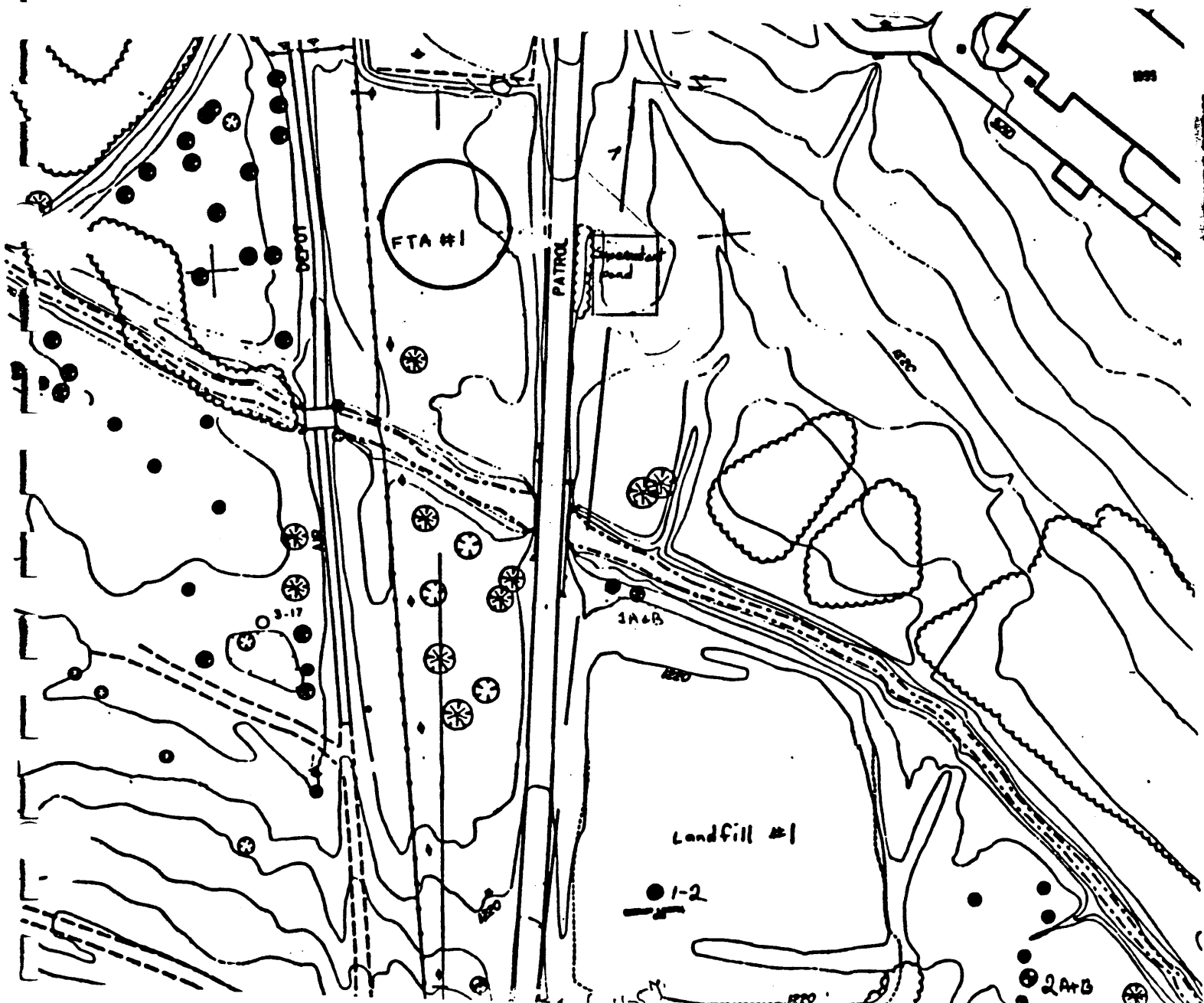
Contaminant Summary: The site was investigated during November, 1983 and January - February, 1984 by Radian Corporation during Phase II of the Installation Restoration Program. Samples of waste material had elevated concentrations of Total Organic Carbon, Total Organic Halogen, cadmium, chromium, and lead. Groundwater monitoring in the area revealed localized groundwater contamination in a shallow well (8 feet deep) in the IWP waste that contained water on an intermittent basis only. Twelve organic priority pollutants were detected in a one-time sampling of that well. Concentrations of all contaminants were less than 10,000 ppb and neither of the other two wells detected any contamination. Based on results of that investigation, a no-action plan was proposed to EPA Region VI, and the Oklahoma State Department of Health. That no-action plan has not been approved as of this date.

N. SUPERNATANT POND

Site Description:

The supernatant pond site is located on Tinker AFB 75 feet east of Patrol Road and approximately 200 feet north of Crutch Creek. This site was possibly used until 1984 as an evaporation pond for industrial operations at the building on the west side of Patrol Road that houses the current O₂ facilities. Very little is known about the site at this time. It was shown on base maps as early as 1954 with a 10 inch sanitary sewer pipe connecting it to the building mentioned above. Several of the maintenance personnel at Tinker AFB remember the lagoon and have indicated that it was a concrete structure that resembled a swimming pool. They also have reported that during and after a heavy rain it often overflowed, draining down into Crutch Creek. The investigations on this site will be done in FY 89 and will consist in installation of monitoring wells, boreholes, and soil gas survey. Samples of the water and soil at the site will be analyzed for chemical and physical characterization.

Contaminant Summary: No information is available at this time..



ATTACHMENT 2

DIRECT READING LOGS

AIR MONITORING WORKSHEET
TINKER AIR FORCE BASE

DATE: _____

Site: _____

Activity: Drilling Soil/Gas _____ Groundwater Sampling_____ Other (explain)

Instrument:

(P) - Photoinization Meter,	Type <u>ANU</u>	Unit/Model <u>PM-1</u>	Calibration <u>Date/Time</u>
(C) - Combust Gas/O ₂ Meter,	Type <u>Gastech</u>	Unit/Model <u>1214</u>	Calibration <u>"</u>
(HS)- Hydrogen Sulfide,	Type <u>Ind Sci</u>	Unit/Model <u>HM 271</u>	Calibration <u>"</u>
(DT)- Detector Tubes,	Type <u>SKC</u>	Unit/Model <u>Benzene</u>	Calibration <u>none</u>

Monitoring Requirements: Drilling: sample with PM in employees Breathing Zone every 30 min. Sample well with Combust gas rate every 30 min. Samples for PM sample every test sample.

General Comments: 3 man Drill Crew - weather is rising 150°F. Using auger and drilling 15' wells.

READINGS:

Time	Instr.	Reading	Location	Comments
0900	P	3 units	Well #4, 3001	At the well opening
0901	C	0 %	" "	" "
0915	P	0 units	" "	B.Z of Rick
0916	C	0 %	" "	" "
0920	HS	0 %	" "	" "
0920	HS	0 %	" "	At the well opening.
0925	DT	3 ppm	" "	Benzene " "
0926	DT	0 ppm	" "	B.Z of Rick
0930	P	2 units	" "	At the well opening
0931	P	0 "	" "	BZ of Tom
0933	C	0 %	" "	" "
0945	C	10 %	" "	Drilling and removed auger, strong smell of solvent and vapor on the auger.
0946	C	0 %	" "	B.Z of Rick over the hole
SAMPLE				Use Back for Additional Readings and diagrams

DATE: _____

Site: _____

Instrument:

Monitoring Requirements: _____

General Comments: _____

[illegible]

2 Prepared by

ATTACHMENT 3

MEDICAL/CHEMICAL INFORMATION

REPRODUCED AT GOVERNMENT EXPENSE

Elkins recommended 5 ppm (1959); Smyth commented that, based on acute toxicity, a limit less than half that for acetic acid would be more consistent.⁽⁶⁾

References:

1. *Chemical Condensed Dictionary*, 8th ed., p. 129, Van Nostrand Reinhold Co., NY.
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3. Henderson, Y., Haggard, H.W.: *Noxious Gases*, p. 129, Reinhold Publishing Co., NY (1943).
4. Fairhall, L.T.: *Industrial Toxicology*, p. 203, Williams & Wilkins, Baltimore, MD (1949).
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ACETONE

2-Propanone



TLV, 750 ppm (\approx 1780 mg/m³)

STEL, 1000 ppm (\approx 2375 mg/m³)

Acetone is a colorless, highly volatile, flammable liquid with an aromatic odor. It has a molecular weight of 58.08, a specific gravity at 25° C of 0.788 and a vapor pressure at 20° C of 180 Torr. The closed cup flash point is 1.4° F and the upper and lower explosive limits in air are 10.3% and 2.9%, respectively. It boils at 56.5° C, melts at -94° C and is soluble in all proportions in water, alcohol and ether. Its odor threshold is reported to be between 200 and 400 ppm.⁽¹⁻³⁾

Acetone is a widely used industrial solvent and chemical intermediate. It is found in paints, varnishes, lacquers, and is used as a solvent for cements in the leather and rubber industries. The evaporation rate of acetone makes it also quite useful for cleaning and drying precision parts.

Inhalation of acetone vapors in high concentrations produces dryness of the mouth and throat, dizziness, nausea, incoordinated movements, loss of coordinated speech, drowsiness, and in extreme cases coma.

Acetone concentration of 52,200 ppm was found to produce narcosis in rats and was fatal at 126,600 ppm for 1 hour.⁽⁴⁾ Acute acetone intoxication was reported in a 10 year old boy who wore a hip cast set with a mixture of 90% acetone, 9% pentane and 1% methyl salicylate. The following symptoms were described: restlessness, headache, vomiting (positive benzidine for blood), stupor, blood pressure 80/60, rapid and irregular respiration rate. The relative amounts of acetone inhaled and percutaneously absorbed were not determined. However, according to authors who have considered this problem, the degree to which acetone is absorbed through the skin under ordinary circumstances is quite small.^(4,6) The effects of acetone on workers who were cleaning a pit were described by Ross:⁽⁷⁾ eye and throat irritation, weakness of legs, headache, dizziness and lightheadedness. One of the workers fainted. Acetone concentrations in the pit 3 and 18 hours and 1 week after the incident were in excess of 12,000 ppm. Ingestion of 200 mL of acetone by a 42 year old man⁽⁸⁾ made him stuporous 0.5 hours later and produced flushed cheeks and shallow respiration. He later lapsed into coma, but regained consciousness in about 12 hours when given supportive therapy.

Inhalation of small quantities of acetone vapors over long periods causes irritation of the respiratory tract, coughing and headache.

Vigliani and Zurlo⁽⁹⁾ examined workers engaged in the production of acetone where concentrations were reported to be 700 ppm for 3 hours/day for 7-15 years. He reported inflammation of the respiratory tract, stomach and duodenum, attacks of giddiness and loss of strength. No mention was made of other solvent exposures. Raleigh and McGee⁽³⁾ studied workers who cleaned filter press plates that contained a thick syrup-like compound of cellulose acetate dissolved in acetone. Acetone concentrations when pulling down filters which was done 3 hours per shift ranged from 155 to 6596 ppm. At other times acetone concentrations were in the range of 25 to 904 ppm. The daily time weighted averages were in the range of 950 to 1060 ppm. Eye irritation was noted by 7 of 9 workers. Other symptoms reported less frequently included headache, lightheadedness, nasal irritation and throat irritation. The report states that the symptoms were intermittent, transient and occurred when concentrations of acetone in air were considerably in excess of 1000 ppm. A review of the raw data, however, indicates that at least four instances of eye irritation occurred from exposures below 1000 ppm. DiVincenzo *et al*⁽²⁾ exposed nine male employees to acetone vapor concentrations of 100 and 500 ppm for 2 to 4 hours. No symptoms were reported at 500 ppm although they did note an awareness of acetone at this concentration. Nelson *et al*⁽¹¹⁾ subjected 10 men to acetone vapor for 3-5 minutes in a fume chamber. The highest concentration they considered satisfactory was 200 ppm. A slight irritation was experienced at 300 ppm, but 500 ppm was still tolerated by most subjects.

No reports were seen in the literature that implicated acetone as a carcinogen or mutagen. Smyth *et al*⁽¹⁰⁾ reported an oral LD₅₀ in rats to be 10.7 mL/kg.

Nelson *et al*⁽¹¹⁾ reported slight irritation at 300 ppm, but this was based on extremely short, 3 to 5 minutes, exposures. DiVincenzo *et al*⁽²⁾ on repeated 2 to 4 hours exposures found no effects from acetone at 500 ppm except an awareness of odor. The raw data of Raleigh and McGee indicate that mild irritation was experienced by some of the workers in their study at acetone exposures below 1000 ppm. On the basis of these findings a recommendation is made that a TLV of 750 ppm be adopted for acetone, with a STEL of 1000 ppm.

NIOSH in its criteria document for ketones⁽¹⁴⁾ recommends an exposure limit of 250 ppm for acetone, based largely on complaints of workers with exposures of 1000 ppm or less, together with the human subject experiments of Nelson *et al*⁽¹¹⁾. In the judgment of the Committee this limit is unnecessarily severe, in view of the widespread use of acetone without evidence of serious ill effects, even at much higher concentrations.

Other recommendations: The following reported in 1970⁽¹¹⁾ Bulgaria, Hungary and Poland 83 ppm; Romania 210

BARIUM

Ba

Soluble Compounds, as Ba

TLV, 0.5 mg/m³

Barium, atomic number 56, atomic weight 137.3, is an alkaline earth element in Group IIA of the periodic table. The metal is extrudable and machinable, but is highly reactive, being oxidized in air and reacting with water with the release of hydrogen. Barium has a specific gravity of 3.5 at 20° C, a melting point of 710° C and a boiling point of 1527° C. It is soluble in alcohol, but insoluble in benzene.

Important compounds include the carbonate (ceramics, rodenticide), chloride (chemicals), chromate (pigments), hydroxide (water treatment, ceramics), nitrate (pyrotechnics), oxide (lubricants) peroxide (bleach), and sulfate (pigment and filler). Of these BaSO₄ is sufficiently insoluble to be considered non-toxic, and is employed as an opaque medium in gastro-intestinal radiography.

The clinical entity "baritosis" has been reported in the industrial hygiene literature sporadically since 1934 when Leschke⁽¹⁾ described a case with almost fatal outcome in a baryta worker who had apparently inhaled ample quantities. Other reports of industrial exposure to barium compounds with or without exposure to lithopone have described pulmonary nodulation with or without decrease in lung function, such as dyspnea on exertion.^(2,3) More soluble forms of barium, as the carbonate, oxide and nitrate, tend to be more injurious, particularly acutely. Dusts of barium oxide are considered potential agents of dermal and nasal irritation.⁽⁴⁾

The pharmacologic action of barium is well known;⁽⁵⁾ chief among the actions of barium is its effect on muscle, particularly cardiac, increasing its excitability. Skeletal, arterial, intestinal and bronchial muscle are all affected by barium. In addition, effects on the hematopoietic system have been noted, as well as on the cerebral cortex.

Fazekas *et al*⁽⁶⁾ have reported that subcutaneous injection of an aqueous solution of barium chloride at a dosage of 5 mg/kg caused acute toxicity with death after 2-2.5 hours. Chronic poisoning was achieved by the injection of solutions at 10, 5 and 2 mg/kg. Rabbits in this series were killed at 98 to 193 days. Effects on the central nervous system are described.

The present limit of 0.5 mg Ba/m³ of air was suggested by Hyatt,⁽⁷⁾ who employed this limit for a number of years at the Los Alamos Laboratories with satisfactory results for the control of exposure to barium nitrate. It is not known what degree of added safety this limit incorporates. Brown *et al*⁽⁸⁾ conducted tests for acute toxicity and inhalation effects with zirconium lactate and barium zirconate in the rat. The oral LD₅₀ dose was greater than 10 g/kg for zirconium lactate and 1.98 g/kg for barium zirconate. Groups of 10 guinea pigs, 10 rats and 10 hamsters were exposed for a period of 225 days to either 15 or 150 mg/m³ of zirconium lactate, to 15 mg/m³ of barium zirconate, or to room air. Exposed animals showed poor weight gain, pathological changes consistent with a chronic interstitial pneumonitis, very little deposition of fibrous tissue, no granuloma, and an increase in the zirconium content of the lung tissue.

Thomas *et al*⁽⁹⁾ studied the *in vivo* solubility, in rats, of barium chloride, carbonate, sulfate and barium fused into clay. The chloride and carbonate disappeared rapidly from the injection site. The sulfate dissolved more slowly; a half life of 26 days was calculated. The fused clay was largely retained, the half life being calculated as 1390 days.

These data, and others cited by the authors, suggest that BaSO₄ cannot be considered inert for chronic exposure. Therefore, the Committee recommends a TLV of 0.5 mg Ba/m³ for compounds of barium.

Other recommendations: all jurisdictions that have adopted limits for barium compounds have accepted the TLV of 0.5 mg/m³.

References:

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6. Fazekas, I.G., Felkai, B., Melegh, B.: *Arch. Path. Anat. Physiol.* 324:110 (1953).
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CADMIUM AND COMPOUNDS

Cd

Dust, Salts and Cadmium Oxide Fume, as Cd, and Cadmium Oxide Production

TLV, 0.05 mg/m³ — Dusts, Salts & Cadmium Oxide Production

STEL, 0.2 mg/m³ — Dusts & Salts

CEILING LIMIT, 0.05 mg/m³ — Cadmium Oxide Fume

Cadmium is a metallic element, atomic number 48, atomic weight 112.4, in Group IIB of the periodic table. It is a soft, blue-white, malleable metal with a specific gravity of 8.642. The boiling point is 767° C and melting point is 320.9° C. At the melting point, the vapor pressure is 0.095 mm, and even at 157° C the solid has a significant vapor pressure of 0.000021 mm, corresponding to 0.12 mg/m³ at room temperature. When heated in air, it burns readily and is dissolved by acids and ammonium nitrate solutions. It is insoluble in water.

Cadmium oxide (CdO) may be in the form of a colorless amorphous powder or as red or brown crystals; it is formed when cadmium is burned or heated. CdO, and cadmium hydroxide and carbonate, are soluble in dilute acids and ammonia solutions. The chloride, sulfate, nitrate and most other salts are either soluble in water or dissolved by dilute acids and/or ammonia solutions. The sulfide, selenide and telluride are colored (yellow, red and black) and practically insoluble in water.

Cadmium is used as a coating for other metals, in bearing, brazing and low-melting alloys, in nickel-cadmium storage batteries, and reactor control rods. Cadmium compounds are employed as TV phosphors, pigments in glazes and enamels, dyeing and printing textiles, photography, dry film lubricants, lasers, lithography, plastic stabilizers, semiconductors, pyrotechnics, rectifiers, solar cells, scintillation counters.

Inhalation overexposure to the intensely irritating, freshly generated fume of heated cadmium has often produced an acute poisoning whose symptomatology, usually delayed for several hours, includes severe tracheobronchitis, pneumonitis and pulmonary edema, with a mortality rate of about 20 percent and no similarity with chronic cadmium poisoning. Average concentrations responsible for fatal cases have been estimated at 50 mg/m³(1,2) and 40 mg/m³(3) both for exposures of one hour; and 9 mg/m³ for five hours.(4) Nonfatal pneumonitis has been reported from concentrations between 2.5 and 0.5 mg/m³(5) Relatively mild cases resembling metal fume fever and often with some symptoms and signs of acute gastroenteritis have been attributed to even lower concentrations.(6) In one such case, these ranged from 0.15 to 0.01 mg/m³ for a nine-hour exposure which, however, also included simultaneous exposure to other acute pulmonary irritants.(3) Tho-

see surviving an episode of acute poisoning recover without developing any chronic effects, such as proteinuria.

Inhalation of cadmium dusts, salts and fume over a number of many years result in chronic cadmium poisoning, a disease characterized by a distinctive, nonhyperthrophic emphysema with or without renal tubular injury, in which urinary excretion of a protein of molecular weight of 20,000 to 30,000 occurs. This protein does not react to routine proteinuria tests, and is by itself an indicative sign of early but reversible chronic poisoning. Further inhalation overexposure results in irreversible renal tubular damage, which may progress into a complete Fanconi syndrome with decreased tubular reabsorption of proteins, glucose, amino acids, calcium phosphorus, and with decreased ability to acidify and concentrate the urine. Other reported toxic effects include anemia, eosinophilia, anosmia, chronic rhinitis, yellow discoloration of teeth and bone changes.(7-10)

Princi(11) studied 20 American cadmium smelter workers exposed to concentrations of cadmium fume ranging from 6.59 to 0.98 mg/m³; cadmium oxide dust of 17.23 mg/m³ and cadmium sulfide of 31.30 mg/m³. They reported generally lower than expected hemoglobin concentrations and red blood cell counts, and an increased number of eosinophiles, as well as a yellow ring on teeth of 9 of the 15 workers who still had their own teeth. High urinary specific gravity values were found in all cases and ascribed to the higher urinary concentrations expected during the summer months of the study. Results of other routine clinical tests were not reported, although the boiling test for protein was negative in all cases.(12) No special tests for cadmium proteinuria or pulmonary function studies were done.

The possibility of chronic cadmium toxicity was reported by Hardy and Skinner(13) in 5 of 8 workers engaged in making cadmium-faced bearings which involved melting and pouring cadmium. The average exposure was estimated to be 0.1 mg/m³, range trace to 0.4 mg/m³. The opinion was based in general findings of pallor, fatigue, loss of appetite, sternal and abdominal pain and detectable amounts of cadmium in the urine.

Two cases of fatal emphysema were reported in workers making copper-cadmium alloy by Lane and Campbell(14) which involved adding cadmium (boiling point, 767° C) to molten copper (melting point, 1083° C). General foundryroom air concentrations determined during 3 years prior to report, averaged 0.17 mg Cd/m³, range, (0.07-0.4). No estimates of the cadmium level over the pots where the workers were standing were given, nor were estimates made of the levels existing in the late twenties and mid-forties when exposures were incurred. The cadmium content of the lung was 277 µg/100g, that of the kidney, 233, and of the liver, 25 µg/100g.

A similar report of emphysema and proteinuria in workers engaged in copper-cadmium alloy casting was made by Bonnell.(15) Of 83 workers exposed to cadmium fume, cadmium was present in the urine of 62, and 41 had values exceeding more than 30 µg Cd/day. Some of those with

mg/m³ is based on effects other than carcinogenicity or teratogenicity, which NIOSH apparently considers unproven for cadmium.

The Committee on Hygiene Standards of the British Occupational Hygiene Society also believes the evidence inadequate to conclude whether or not there is a causal relationship between cadmium and cancer in man.⁽³⁸⁾ The BOHS recommends three TWA standards for cadmium in air: 0.05 mg/m³ for the respirable fraction of all compounds; 0.2 mg/m³ for the acid (0.1 NHCl) soluble portion of total dust, both as cadmium; and the 10 mg/m³ nuisance dust limit for dust above the respirable range and insoluble in acid. A Special Short Exposure Limit for cadmium fume of 2 mg/m³ for a maximum time of ten minutes is also proposed, predicated on no exposure for the remainder of the shift.

It appears from the foregoing, a TLV for the cadmium worker must prevent proteinuria, pulmonary edema and emphysema. Evidence for an added risk from carcinoma of the lung and prostate is greatest among workers engaged in smelting cadmium, where substantial exposure to other toxic fumes, gases and dusts appears to be the rule. Most of the data on cadmium levels responsible for these observed effects have indicated exposures above the former TLV of 0.1 mg/m³. Accordingly, a TLV of 0.05 and a STEL of 0.2 mg Cd/m³ for all forms of dusts and salts and ceiling limit of 0.05 mg Cd/m³ for cadmium oxide fume should provide adequate protection, barring simultaneous excessive or borderline exposure to other toxic or irritating impurities.

Based on the NIOSH⁽²²⁾ and the BOHS⁽²⁸⁾ findings, the A2 designation as a suspected carcinogen has been removed for cadmium oxide production and a time-weighted TLV of 0.05 mg/m³ is now recommended.

Other recommendations, all as cadmium in mg/m³: USSR (1976) stearate and oxide dusts 0.1, oxide fume 0.03; West Germany (1974) oxide fume 0.1; East Germany (1973) fume and dust 0.09; Czechoslovakia (1969) fume 0.1; Sweden (1975) dust 0.05, fume 0.02.

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CALCIUM CYANAMIDE



Calcium Carbimide



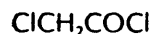
TLV, 0.5 mg/m³

STEL, 1.0 mg/m³

Commercial calcium cyanamide is a crystalline gray material composed of 20-24% N, 12% C (graphite), 12-15% CaO and small amounts of sulphides, oxides, nitric silicon, iron and aluminum. It has a molecular weight of

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CHLOROACETYL CHLORIDE



Skin

TLV, 0.05 ppm ($\approx 0.2 \text{ mg/m}^3$)

Chloroacetyl chloride is a colorless liquid with a pungent odor. Its molecular weight is 112.94; a specific gravity of 1.4202 (20/4° C); boiling point of 105-110° C; vapor pressure at 20° is 19 mm Hg. It decomposes in water and is non-flammable.

Its chief use is as an intermediate in the manufacture of chloroacetophenone and other chemicals.

The oral LD₅₀ for rats lies between 0.12 and 0.25 gm/kg. It is corrosive to the skin and eyes, and can be absorbed through the skin in lethal amounts. A 5-10 minute inhalation exposure at 4 ppm caused respiratory difficulties in rats, but no effect was observed from inhalation of 2.5 ppm for seven hours.⁽¹⁾

A 30-day inhalation study with rats, mice and hamsters showed eye and respiratory irritation at 2.5 ppm; the no ill effect level was 0.5 ppm.

Medical reports of the effects of acute exposure include: mild to moderate skin burns and erythema; lachrymation and mild eye burns; mild to moderate respiratory effects with cough, dyspnea and cyanosis; and mild gastrointestinal effects.

Industrial hygiene surveys revealed 8-hour TWA exposure of 9 to 17 ppb, with excursions to 140 ppb. At the latter concentration eye irritation and minimal respiratory irritation were noted.⁽¹⁾

The toxicity of this compound is illustrated by one unpublished incident, in which a worker was drenched by a surge of a reaction mixture containing chloroacetyl chloride from a reaction vessel.⁽²⁾ Other ingredients of the mixture included xylydine, which was being acetylated to form xylocaine, benzene and sodium carbonate. Although immediately put under a shower he suffered extensive first and second degree burns and pulmonary edema, and three episodes of cardiac arrest occurred during emergency treatment. He went into a coma, due apparently to anoxia induced brain damage, which persisted for several weeks. The ultimate outcome is not known.

Other workers involved in the rescue of the above employee suffered blisters on the hands, and complained of tightness of the chest and slight nausea up to two days later.⁽²⁾

A time weighted average TLV of 0.05 ppm (50 ppb), or one tenth the no effect level for animals exposed for 30 days, is recommended.

Reference:

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2. Pagnotto, L.D.: Personal communication (1978).

CHLOROBENZENE

Monochlorobenzene



TLV, 75 ppm ($\approx 350 \text{ mg/m}^3$)

Chlorobenzene is a colorless liquid with an odor described as almond-like. It has a molecular weight of 112.56 and a specific gravity at 20° C of 1.107. The boiling point is 131.6° C, freezing point is -45° C and has a vapor pressure of 8.8 mm Hg at 20° C. The flash point is reported to be 85° F. It is insoluble in water, but is freely soluble in ether, chloroform, alcohol and benzene.

It finds some use as a solvent, and is an intermediate in the manufacture of other chemicals.

Animals exposed at 1200 ppm showed definite narcotic symptoms, but 220 to 660 ppm could be tolerated.⁽¹⁾ Re-

peated exposures at 1000 ppm resulted in lung, liver and kidney changes;⁽²⁾ at 475 ppm slight liver changes were observed; no effects were noted at 200 ppm.

The toxic effects of chlorobenzene seem to be those of a chlorinated hydrocarbon; the hematopoietic effect of the parent hydrocarbon (benzene) appears to be absent.⁽³⁾ Occupational intoxication has not been reported.

Cook⁽⁴⁾ proposed 75 ppm as a TLV in 1945, citing the U.S. Public Health Service. It is believed that this limit is low enough to prevent narcotic effects or chronic poisoning.

The AIHA Guide (1964) considered 75 ppm too high. As of 1977 Czechoslovakia, Finland, West Germany and Italy recommended approximately 50 ppm; Romania, 20 ppm; other Eastern European nations, 10 ppm; the remaining Western European countries, as well as Japan, 75 ppm.

Spray workers exposed at 0.5% Dursban emulsion in field trials for malaria control on premises showed a measurable decrease in plasma and red cell cholinesterase levels.⁽¹⁰⁾ In this study, 5 of 7 sprayers showed more than 50 per cent reduction in cholinesterase within two weeks after the spraying program began. In another study,⁽⁶⁾ human volunteers were exposed to thermal aerosols containing Dursban insecticide for one period. Exposures of 3 to 8 minutes at concentrations of about 0.8 $\mu\text{m}/\text{m}^3$ in air produced no significant alteration of cholinesterase levels. This concentration resulted from the recommended application rate in thermal fogging.

Available studies indicate that Dursban is rapidly metabolized in the animal body.⁽⁸⁾

There was evidence of teratologic or reproductive effects in male and female rats fed 1.0 mg/kg per day during a three-generation reproduction and fertility study.⁽¹¹⁾

A TLV of 0.2 and a STEL of 0.6 mg/m³ are recommended to prevent any measurable decrease in plasma cholinesterase activities and provides a very wide margin of safety in preventing cholinergic symptoms or organic injury.

CHROMIUM

Cr

Metal and Inorganic Compounds, as Cr

TLV, 0.5 mg/m³ — Metal

0.5 mg/m³ — Cr II Compounds

0.5 mg/m³ — Cr III Compounds

0.05 mg/m³ — Water Soluble Cr VI Compounds

0.05 mg/m³, Appendix A1a — Recognized Carcinogen
— Certain Water Insoluble Cr VI Compounds

Chromium is a metallic element; atomic number 24, atomic weight 51.996, in Group VIB of the periodic table. It is a steel-gray, lustrous metal, with a specific gravity of 7.20. The melting point is 1900° C and boils at 2642° C. The metal reacts with dilute hydrochloric acid and sulfuric acid, but not with nitric acid.

Chromium metal was first isolated in 1798. The chief uses of chromium and chromium compounds are in stainless and alloy steels, refractory products, tanning agents for leather, pigments, electroplating, catalyst and in corrosion resistant products. Chromium is obtained from chromite ores ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$). Relatively large deposits of chromite ore were found near Baltimore in the United States but no mining has taken place there since 1961.

Chromium can have a valence of 2, 3 or 6, and a wide range of chromium alloys and inorganic chromium compounds are encountered in the workplace. These chromium compounds vary greatly in their toxic and carcinogenic effects. For this reason it is necessary to divide chromium and its inorganic compounds into a number of groupings — each with its specific TLV based on available toxicological and epidemiological evidence. These groupings are:

1. Chromium metals and alloys

This grouping includes chromium metal, stainless steels and other chromium-containing alloys.

References:

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2. Divalent chromium compounds (Cr^{2+}) (Chromous compounds)

This grouping includes chromous chloride (CrCl_2) and chromous sulfate (CrSO_4).

3. Trivalent chromium compounds (Cr^{3+}) (Chromic compounds)

This grouping includes chromic oxide (Cr_2O_3), chromic sulfate ($\text{Cr}_2[\text{SO}_4]_3$), chromic chloride (CrCl_3), chromic potassium sulfate ($\text{KCr}[\text{SO}_4]_2$) and chromite ore ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$).

4. Hexavalent chromium compounds (Cr^{6+})

This grouping includes chromium trioxide (CrO_3) — the anhydride of chromic acid — chromates (e.g., Na_2CrO_4), dichromates (e.g., $\text{Na}_2\text{Cr}_2\text{O}_7$) and polychromates. Certain hexavalent chromium compounds have been demonstrated to be carcinogenic on the basis of epidemiological investigations on workers and experimental studies in animals. In general, these compounds tend to be of low solubility in water and thus may be subdivided into two subgroups:

(a) Water soluble hexavalent chromium compounds

These include chromic acid and its anhydride, and the monochromates and dichromates of sodium, potassium, ammonium, lithium, cesium and rubidium.

(b) Water insoluble hexavalent chromium compounds

These include zinc chromate, calcium chromate, lead chromate, barium chromate, strontium chromate and sintered chromium trioxide.

Hexavalent Chromium

The first cases of occupational health effects from hexavalent chromium were reported in 1827⁽²⁾ by Cumin, who observed cases of skin ulceration and dermatitis in dye workers handling potassium dichromate. Mackenzie⁽³⁾ in

1884 reported that perforation of the nasal septum occurred in workers exposed to potassium bichromate. Da-Costa *et al*⁽⁴⁾ in 1916 described chrome ulcers in tanners and dryers. Parkhurst⁽⁵⁾ in 1925 reported chrome dermatitis in blueprint workers exposed to potassium dichromate. Bloomfield and Blum⁽⁶⁾ reported on their study of electroplaters exposed to acidic mist of hexavalent chromium compounds. They noted that 20 or 23 workers examined showed evidence of perforated or ulcerated nasal septa and skin ulcers (*chrome holes*). The Factory Inspectorate in Great Britain⁽⁷⁾ reported in 1930 on the results of medical examinations of 223 persons engaged in chromium plating; 42.6% had dermatitis or skin ulcers and 52% had perforated or ulcerated nasal septa.

The occupational health literature affords abundant evidence that hexavalent chromium compounds may cause irritant and allergic contact dermatitis, skin ulcers, and nasal irritation varying from rhinitis to perforation of the nasal septum. Dermatitis from exposure to soluble hexavalent chromium has been reported in lithographers^(8,9) diesel repair shop workers⁽¹⁰⁾ and leather workers.⁽¹¹⁾ Soluble chromates in cement have been stated to be the cause of cement dermatitis in some workers.⁽¹²⁾

Attempts have been made to correlate the airborne levels of hexavalent chromium with irritation of the nasal mucosa. In the study by Bloomfield and Blum,⁽⁶⁾ electroplaters were exposed to estimated exposures ranging from 0.06 to 2.8 mg/m³ (as Cr⁶⁺). Levels of Cr⁶⁺ in the form of chromium trioxide, were capable of giving rise to nasal irritation at concentrations as low as 0.06 mg/m³. It is difficult to rule out the importance of personal hygiene in the production of nasal symptoms from direct transfer of chromium (Cr⁶⁺) to the nasal mucosa. Nasal irritation is produced from exposure to soluble chromate and bichromate salts as well as to chromic acid mist.^(12,13) The study by the U.S. Public Health Service⁽¹⁴⁾ noted that the mean concentration of water-soluble chromium in plants where nasal irritation was encountered was 0.068 mg/m³ as Cr⁶⁺.

Epidemiological studies showing an increased incidence of lung cancer among workers involved in the manufacture of chrome pigments have been reported from Germany,⁽¹⁵⁾ Norway⁽¹⁶⁾ and United States.⁽¹⁷⁾ Machle and Gregorius⁽¹³⁾ first reported increased incidence of lung cancer in the United States chromate industry. Baetjer⁽¹⁸⁾ carried out a case control study and confirmed the increased risk of lung cancer among the U.S. chromate workers. Mancuso and Hueper⁽¹⁹⁾ attempted to estimate the airborne exposures to chromium in those who developed lung cancer. They found that these workers were exposed to 0.01 to 0.15 mg/m³ of water soluble chromium and 0.1 to 0.58 mg/m³ of water insoluble chromium. The insoluble fraction was denoted as Cr³⁺ and the soluble as Cr⁶⁺ but it is impossible to assign Cr⁶⁺ or Cr³⁺ exclusively to either fraction.

The chromate workers in the preceding studies were exposed to various Cr³⁺ and Cr⁶⁺ compounds as well as to other substances. In general, the evidence does not suggest that chromite ore, a water insoluble Cr³⁺ substance, is a carcinogen. While the evidence is incomplete it does appear that certain Cr⁶⁺ compounds, mainly water insoluble, were involved in increased risk of lung cancer. The experimental data from animals supports the view that water insoluble Cr⁶⁺ compounds, e.g., chromic and zinc chro-

mates, are carcinogenic, whereas the soluble forms are not.⁽²⁰⁾ Royle,⁽²¹⁾ however, has reported an increase in lung and other cancers in chrome platers in England.

Hexavalent chromium compounds have been said to also cause kidney damage in workers^(22,23) where absorption through damaged skin has occurred.

The TLVs for hexavalent chromium compounds are recommended as follows:

- (a) Water soluble hexavalent chromium compounds (see examples noted above). A TLV of 0.05 mg/m³ as water soluble Cr⁶⁺ is considered adequate to protect against irritation of the respiratory tract and possible kidney and liver damage. NIOSH in the criteria document on chromic acid⁽²⁴⁾ recommended that occupational exposures be controlled to prevent exposures above 0.05 mg/m³ TWA. In a later criteria document on hexavalent chromium⁽²⁵⁾ NIOSH recommended a permissible exposure limit of 0.025 mg/m³.
- (b) Certain water insoluble hexavalent chromium compounds (see examples noted above). A TLV of 0.05 mg/m³ as water insoluble Cr⁶⁺ and insertion in appendix A1a is recommended. There is, unfortunately, little previous environmental data from those exposures associated with increased respiratory cancer risk. With the data available, however, this TLV provides an adequate margin of safety. NIOSH recommended a permissible exposure limit of 0.001 mg/m³ for certain insoluble hexavalent chromium compounds.⁽²⁵⁾
- (c) Mixed exposure to soluble and insoluble hexavalent chromium compounds. A TLV of 0.05 mg/m³ as Cr⁶⁺ is recommended.
- (d) Chromite ore processing
Chromate pigment manufacture
It may be advisable to list these process TLVs both as 0.05 mg/m³ as Cr and include them in appendix A1a. This TLV will serve to draw attention to those processes where increased risk of cancer has been associated with chromium compounds.

Chromium Metal

Divalent chromium compounds

(see examples listed earlier)

Trivalent chromium compounds

(see examples listed earlier)

Early studies indicated that divalent chromium and divalent chromium compounds have a low order of toxicity.⁽²⁶⁾ Dermatitis has been reported in workers handling trivalent chromium compounds.^(27,28)

Chest X-rays carried out in workers exposed to chromite dust have been reported to show "exaggerated pulmonary markings"⁽²⁹⁾ and Princier *et al*⁽³⁰⁾ have reported pulmonary disease in workers exposed to ferrochrome alloys with chromium levels in air of 0.27 mg/m³ reported. Other dusts and fumes were present, however, in this plant. Exposure to chromium metal does not give rise to pulmonary fibrosis or pneumoconiosis.

quired an 8-hour exposure at about 6000 ppm (35° C) to kill four of six rats. Signs of gross overexposure were varying degrees of ataxia, prostration, and respiratory distress followed by narcosis. Those that survived appeared to recover without significant signs of exposure.⁽¹⁾

Shell Chemical Corporation⁽¹⁾ presents the following observations in respect to sensory responses reported by unconditioned personnel during or following 5-minute exposures to the vapor:

Threshold, odor	6 ppm
50% Threshold, eye irritation	50 ppm
50% Threshold, nose irritation	50 ppm

No incidents of illness caused by industrial handling of EAK have been reported. Workers may complain of odor

and transient eye irritation when handled in poorly ventilated areas when the concentration exceeds 25 ppm, but experience shows that transient responses do not lead to significant systemic effects.⁽¹⁾

Accordingly, the TLV of 25 ppm is recommended as a comfort level for unconditioned workers.⁽²⁾

References:

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ETHYL BENZENE

Phenylethylene



TLV, 100 ppm (\approx 435 mg/m³)

STEL, 125 ppm (\approx 545 mg/m³)

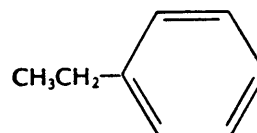
Ethyl benzene is a colorless, flammable liquid with an aromatic odor. It has a molecular weight of 106.16, a specific gravity of 0.86258 at 25° C and a vapor pressure of 7.1 mm Hg at 20° C. The vapor density is 3.7 times that of air. "Saturated" air with the vapor at 26° C and 760 mm is %. It boils at 136.2° C and freezes at -95.01° C. The closed cup flash point is 63° F, autoignition temperature is 810° F and is a fire risk.⁽¹⁾ Ethyl benzene is only slightly soluble in water at 15° C (14 mg/100mL), but is miscible with alcohol and ether.

This compound is employed as a solvent and as an intermediate in the production of styrene.

Ethyl benzene toxicity is characterized by its irritancy to the skin, and less markedly, to the mucous membranes. Repeated application of the liquid to the skin of rabbits causes reddening and some exfoliation and blistering.⁽²⁾ Oettel⁽³⁾ characterized ethyl benzene as the most severe irritant of the benzene series.

On the eyes and nose, the vapor at 5000 ppm causes intolerable irritation; at 2000 ppm, eye irritation and lacrimation are immediate and severe, and are accompanied by moderate nasal irritation, decreasing somewhat in several minutes; at 1000 ppm, irritation and tearing, but tolerance develops rapidly; and at 200 ppm, the vapor has a transient irritant on human eyes.⁽¹⁾

Like benzene, its acute toxicity is low; the dose fatal to guinea pigs in a few minutes was 10,000 ppm⁽⁴⁾ and 5000 ppm dangerous to life in 30 to 60 minutes; animals dying



from exposure had intense congestion and edema of the lungs, and generalized visceral hyperemia. The narcotic dose for animals was 10,000 ppm, reached in 18 minutes, preceded by vertigo, unsteadiness and ataxia.

Chronic inhalation exposure of guinea pigs, monkeys, rabbits and rats at concentrations from 400 ppm to 2,200 ppm, seven to eight hours/day, five days/week for as long as six months, produced no effects in all species except the rat, which showed a slight increase in the weights of the kidneys and livers, on the average, for those exposed at 400 ppm for 186 days. The investigators concluded that 400 ppm was the *beginning effect* level for chronic inhalation of the vapor.⁽²⁾

It is apparent that, as no systemic effects can be expected at levels producing distinctly disagreeable skin and eye irritation, the TLV must be based on the latter effects. For the prevention of disagreeable irritation, a TLV of 100 ppm and a STEL of 125 ppm are recommended.

Other recommendations: Czechoslovakia (1976) 45 ppm; Poland (1975) 25 ppm.

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LEAD

Pb

Inorganic Compounds, Dust and Fume, as Pb

TLV, 0.15 mg/m³

STEL, 0.45 mg/m³

Lead is a metallic element, atomic number 82, atomic weight 207.2, in Group IVB of the periodic table. This heavy, ductile, gray metal has a specific gravity of 11.35, melting point of 327.4° C and a boiling point of 1755° C. Its vapor pressure becomes significant, from a health standpoint, only above 500° C. Only a few lead compounds are appreciably soluble in water, but many are dissolved by acids and most are sufficiently soluble in body fluids to be toxic, especially when inhaled in finely divided form.

Metallic lead finds wide industrial use where its properties of high density, softness, low melting point, resistance to corrosion and/or opacity to gamma and X-rays are needed. It is a major component of many alloys such as solder, type metal and many bronzes. Lead compounds have a wide variety of uses, especially as paint pigments, in storage batteries and ceramics.

Despite the tremendous importance of lead as an occupational hazard, only a handful of papers in the voluminous literature on lead poisoning present meaningful data relating to the threshold limit value. The chief reason for this situation is probably the fact that most authorities rely primarily, if not exclusively, on other tests for estimation of the degree of lead hazard. Urinary and blood leads, urinary coproporphyrin and delta aminolevulinic acid, as well as blood examination for stippled cells and other abnormalities, are among the preferred procedures.

A limit of 0.5 mg/m³ for lead in air was proposed by Legge in 1912, with the comment that, if adhered to, cases of encephalopathy and paralysis would never, and cases of colic would very rarely, occur.⁽¹⁾ The data of Duckering's experiments on the quantities of lead in the air from various industrial processes are given as evidence.⁽²⁾ This value (0.5 mg/m³) was quoted by Alice Hamilton in 1925, with a similar comment.⁽³⁾

In 1933 Russell *et al.*⁽⁴⁾ following a U.S. Public Health Service survey of a lead storage battery plant, proposed a limit of 0.15 mg/m³ for lead dust and fume in this industry. Eight years later Dreessen *et al.*⁽⁵⁾ published results of a follow-up study and considered that their findings confirmed this value. In 1943 Kehoe and other members of the Committee on Lead Poisoning of the American Public Health Association recommended 0.15 mg/m³ as a time-weighted average limit.⁽⁶⁾

A number of investigators found the 0.15 mg/m³ value difficult to achieve in many industries, and observation of workers, combined with lead urinalysis and similar studies convinced them that this limit was unnecessarily stringent. Winn and Shroyer⁽⁷⁾ concluded that maintenance of the

average concentration of lead dust and fume at or below 0.5 mg/m³, combined with a medical program, would assure adequate control. Weber⁽⁸⁾ considered the 0.15 mg/m³ too low, but stipulated that 0.3 mg/m³ should not be exceeded (as time-weighted average). He found that an atmospheric concentration of 0.43 mg/m³ corresponded to 0.20 mg/L of urine, a level considered by some investigators to represent the upper limit of safety. Elkins⁽⁹⁾ assembled the data available on lead in air and lead in urine and concluded that a urinary lead concentration of 0.20 mg/L would, on the average, correspond to an air-lead value of 0.20 mg/m³.

On the basis of these reports and unpublished data from several sources, the TLV for lead was increased from 0.15 to 0.20 mg/m³ in 1957. Some authorities continued to use the previous limit, however.⁽¹⁰⁾ Schrenk⁽¹¹⁾ implied that the 0.15 mg/m³ value was to be preferred. The preponderance of American opinion, however, seemed to be that the 0.2 mg/m³ limit was adequate to prevent episodes of lead intoxication. Thus Kehoe,⁽¹²⁾ in a discussion of threshold limits for lead, stated that: "Evidence of the validity of the standard (0.2 mg/m³) has been provided elsewhere and need not be enlarged upon here." He went on to warn that this value is adequate only if ingestion of lead is prevented. Johnstone and Miller⁽¹³⁾ referred to the 0.2 mg/m³ limit as generally accepted.

More recent comparisons of atmospheric and urinary lead concentrations have indicated conflicting results. Berg and Zenz,⁽¹⁴⁾ in a foundry study, found that air-lead concentrations between 0.14 and 0.18 mg/m³ resulted in urinary lead values below 0.15 mg/L; 0.28 mg/m³ was associated with 0.17 mg/L of urine.

Tsuchiya and Harashima⁽¹⁵⁾ concluded that for a 48- to 60-hour work week, an average air-lead concentration of 0.10 mg/m³ would bring about an average urinary lead level of 0.15 mg/L; and 0.12 mg/m³ to 0.20 mg/L. Concentrations of 0.12 to 0.14 mg/m³ resulted in increased urinary coproporphyrin, some stippling of blood cells and anemia.

Most extensive lead exposure studies have involved lead oxide dust or the fume of metallic lead. Some reports have indicated that the dusts of certain insoluble lead compounds, such as the sulfide⁽¹⁶⁾ and chromate, were less hazardous than more soluble forms of lead. Thus Harrold and associates^(17,18) studied a group of painters exposed to mists of lead chromate in concentrations averaging between 1.2 and 12 mg of lead per cubic meter of air, and found little evidence of lead absorption or intoxication. They also suggested that lead titanate would present relatively little hazard, due to its very low solubility.

On the other hand, Hartogenesis and Zielhuis⁽¹⁹⁾ found blood changes in workers exposed to lead chromate dust at levels above 0.2 mg/m³ (as lead) and doubtful changes between 0.1 and 0.2 mg/m³. They consider that the TLV for lead chromate should be the same as that for other inorganic lead compounds.

Curiously there is evidence that lead fume is less harmful than equal amounts of the dust of relatively soluble

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METHYLENE CHLORIDE

Dichloromethane



TLV, 100 ppm ($\approx 360 \text{ mg/m}^3$)

STEL, 500 ppm ($\approx 1700 \text{ mg/m}^3$)

Methylene chloride is a colorless volatile liquid, soluble in water to only 1% by weight, but completely miscible with most organic solvents. It has a sweetish odor, like most chlorinated hydrocarbons. The molecular weight is 84.94, a specific gravity is 1.335, boiling point is 40° C and it solidifies at -95° C. With its high vapor pressure (315 mm Hg at room temperature, 23.5° C) substantial concentrations of vapor are readily achieved whenever methylene chloride is spilled or spread out over a large surface, even in a space that is not closely confined. It is non-flammable by standard tests, but will burn in extreme conditions.

Methylene chloride is widely used in paint removers, as a solvent for plastics, as a degreasing agent, in propellant mixtures for aerosol sprays and as a blowing agent in foams. The odor is not a good indication of exposure since concentrations of 100 ppm reportedly are not highly perceptible.

Liquid methylene chloride is painful and irritating if splashed in the eyes or if confined on the skin by gloves, clothing or paint remover formulations. A burn can result if it is not promptly removed from the eyes and skin. The acute oral LD₅₀ for rats is about 2000 mg/kg.

According to Lehmann and Flury,⁽¹⁾ slight narcosis occurs at 4000 to 6100 ppm in several species of animals. The fatal concentration for seven hours' exposure is given by many authorities as about 15,000 ppm.⁽¹⁻³⁾ Rats exposed 75 days (8 hours a day) at 1300 ppm showed slight liver changes which were not found at 50 days.⁽¹⁾ Cats exposed four to eight days at 7200 ppm for four weeks were found to have kidney and liver changes. Heppel and associates⁽⁴⁾ found that daily seven-hour exposures at 5000 ppm for six months had no discernible effect on dogs and rabbits, and only reduction in the rate of growth of guinea pigs. At 10,000 ppm, four hours a day, for seven and one-half weeks dogs and guinea pigs, but not monkeys, rabbits or rats developed liver injury. Moskowitz and Shapiro⁽⁵⁾ reported four cases of poisoning with one fatality, apparently due to narcotic action. Collier⁽⁶⁾ reported two cases of poisoning in painters who suffered from headache, giddiness, stupor, irritability, numbness and tingling in the limbs. Kuzelova and Vlasak⁽⁷⁾ noted complaints of headache, fatigue and irritation of the eyes and respiratory passages by workers exposed at concentrations up to 5000 ppm. Neurasthenic disorders were found in 50%, and digestive disturbances in 30% of the persons exposed. Three acute poisonings, one involving loss of consciousness, were recorded without serious after-effects.

Weiss⁽⁸⁾ stated that a chemist after a year's exposure developed toxic encephalosis with acoustical and optical delusions and hallucinations. Concentrations frequently exceeded 500 ppm; values of 660 ppm, 800 ppm, and near the floor, 3600 ppm were noted.

Golubovski and Kamchatnova⁽⁹⁾ found liver disease in workers exposed to methylene chloride and methanol which they attributed to the former. Exposure concentrations were not reported.

In the early 1940's methylene chloride was considered the least toxic of the chlorinated hydrocarbon solvents when a safe industrial air limit of 500 ppm was proposed by Heppel et al,⁽⁴⁾ and later adopted by the TLV Committee as protective enough to prevent any significant narcotic effects or liver injury.

Subsequently, Stewart et al⁽¹⁰⁾ reported that significant quantities of carbon monoxide and carboxyhemoglobin were produced in humans receiving single exposures at 500-1000 ppm of methylene chloride. The carboxyhemoglobin concentrations reported by Stewart approximated those considered objectionable if due to inhalation of carbon monoxide.

More extensive examination of CO production from methylene chloride was later reported by the same investigators.⁽¹¹⁾ Human volunteers exposed to methylene chloride at 1000 ppm for two hours (2000 ppm-hours, one half of the Ct permitted for an 8-hour exposure at 500 ppm) resulted in carboxyhemoglobin levels in excess of those permitted in industry from exposure to CO alone.

This finding of the body's capacity to metabolize methylene chloride to CO was confirmed by Ratney, Wegman and Elkins⁽¹²⁾ in a small group of workers exposed to 180 to 200 ppm methylene chloride. Such daily, repeated exposures resulted in equilibrium blood concentrations of carboxyhemoglobin of 9% that decreased to half that value by next day's start of work. The differential increment in percent carboxyhemoglobin of 4.5% from a day's exposure at 180 to 200 ppm of methylene chloride is approximately the same as that developed from a daily exposure to CO at its TLV of 50 ppm.

DiVincenzo⁽¹³⁾ found that humans exposed to 100 ppm methylene chloride for 8 hours had a carboxyhemoglobin (COHb) value of $3.22\% \pm 0.22\%$, whereas an 8-hour exposure at 150 ppm produced $5.39\% \pm 0.06\%$ level and an 8-hour exposure at 200 ppm resulted in COHb level of $6.8\% \pm 0.65\%$.

In an extensive study several healthy adults of both sexes were exposed from 2-10 times to methylene chloride vapor concentrations of 0.50, 100, 250 or 500 ppm for periods of 1, 3 and 7.5 hours in a controlled environment chamber. These studies were designed to simulate the type of exposures encountered in the industrial setting and consisted of both steady, non-fluctuating vapor concentrations. Exposure resulted in a prompt elevation of carboxyhemoglobin. The elevation persisted longer than COHb from CO alone since metabolism of the absorbed methy-

cant performance decrement was found among these workers when compared against a control group. Although it was determined that methyl chloride exposures below 100 ppm produce significant transitory changes in functional capacity, data are not available to determine the precise point with respect to ambient methyl chloride air concentrations at which this occurs.

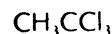
While the current human exposure data indicate no adverse irreversible effects to body organ systems at 100-200 ppm, the work of Repko *et al* indicate that the margin may be small with respect to neurotoxic effects. Therefore, a TLV of 50 ppm is recommended with a STEL of 100 ppm. No current evidence of mutagenic, teratogenic, or carcinogenic effects exists.

Other recommendations: Cook (1945) 200 ppm; Smyth (1956) 100 ppm; Elkins (1959) 50 ppm; ANSI (1969) 100 ppm; USSR (1967) 2.5 ppm; Czechoslovakia (1969), West Germany (1978) and East Germany (1978) 50 ppm.

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METHYL CHLOROFORM

1,1,1-Trichloroethane



TLV, 350 ppm (\approx 1900 mg/m³)

STEL, 450 ppm (\approx 2450 mg/m³)

A water-clear liquid, methyl chloroform has a molecular weight of 133.42, a specific gravity of 1.3376 at 20° C and, at the same temperature, a vapor pressure of 100 mm Hg. It boils at 74.1° C and solidifies at -32.5° C. It burns only in excess oxygen or in air if a strong source of ignition is present. Methyl chloroform is almost insoluble in water, but is miscible with most organic solvents.

The major usage is as a cleaning solvent. Because of its reactivity with magnesium, aluminum and their alloys, inhibitors are generally added to increase the stability of the solvent.

The oral toxicity of methyl chloroform is low. The LD₅₀ for rats, mice, rabbits and guinea pigs was reported to range from 5.7 to 12.3 g/kg.⁽¹⁾ Like many solvents, methyl chloroform will defat the skin and cause redness and scaliness. Absorption through the skin can occur but is not a significant route of toxic exposure; the acute LD₅₀ for rabbits is greater than 16 g/kg. When doses of 0.5 g/kg were applied repeatedly for 90 days to rabbits, no effects were caused except for slight reversible irritation of the skin at the site of application.⁽¹⁾

While comparatively low in systemic toxicity, methyl chloroform is an anesthetic and is capable of causing death when inhaled at concentrations in excess of 14,000-15,000 ppm.⁽¹⁾

Torkelson and associates⁽¹⁾ described the toxicity of methyl chloroform from repeated exposures of animals. Exposure of animals for three months at concentrations from 1000 to 10,000 ppm caused some pathologic changes in the

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2. NIOSH/OSHA Standards Completion Program, Draft Technical Standard and Supporting Documentation for Methyl Chloride.
3. *Occupational Diseases, A Guide to Their Recognition*, p. 208, Revised Edition, DHEW (NIOSH) Pub. No. 77-181 (June 1977).
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9. Scharenweber, H.C., Spears, G.N., Cowles, S.R.: *JOM* 16:112-113 (1974).
10. Repko, J.D. *et al*: *Behavioral & Neurological effects of Methyl Chloride*, DHEW (NIOSH) Pub. No. 77-125 (December 1976).

livers and lungs of some species; the main effect of exposure appeared to be anesthesia. Exposure to the vapor at 500 ppm for seven hours a day, five days a week for six months did not cause any toxic changes of significance in rats, guinea pigs, rabbits or monkeys.

Rowe and associates⁽²⁾ found that the only effect of repeated exposure of several species at 500 ppm of a mixture containing 75% methyl chloroform and 25% perchloroethylene was a slight depression in the growth of guinea pigs, due to a reduced food intake. At 1000 ppm mild reversible liver and kidney changes were detected. A time-weighted average limit of 400 ppm was recommended for this mixture.

Other animal studies confirm the low hepatotoxicity of methyl chloroform,^(3,4) but indicates that cardiac sensitization can occur if exposures are excessive.^(5,6) Studies in dogs given intravenous injections of epinephrin in conjunction with exposure to either 2500, 5000 or 10,000 ppm vapor have been described. Under these exaggerated conditions, no cardiac sensitization was observed at 2500 ppm, but 3 of 18 dogs at 5000 ppm and 12 of 12 at 10,000 ppm were affected.⁽⁶⁾ Other studies in rabbits, rats and mice, as well as human experience in anesthesiology, confirm the cardiac effects of methyl chloroform.^(7,8) Methyl chloroform is poorly metabolized and is excreted unchanged in the expired air of animals and human test subjects.⁽⁹⁾

Methyl chloroform did not produce teratogenic effects in rats or mice exposed 7 hours per day to 875 ppm during the period of organogenesis.⁽¹⁰⁾ Two lifetime cancer studies have been negative. There were no adverse effects of any kind in rats exposed 6 hours per day for 12 months to either 875 or 1750 ppm vapors.⁽¹¹⁾ Groups of rats and mice fed methyl chloroform by gavage in the NCI Bioassay Program showed no increase in tumors over that of the controls.⁽¹²⁾ The dosage levels fed were 1500 and 750 g/kg/day.

Industrial experience has been consistent with the findings in laboratory animals.⁽¹³⁾ Deaths due to anesthesia and/or cardiac sensitization have been reported to have

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4. Dale, K.: *Scand. J. Resp. Dis.* 54(3):168-184 (1973).

5. National Cancer Institute: *Bioassay of Titanium Dioxide for Possible Carcinogenicity*, DHEW Pub. No. (NIH) 78-1347, Bethesda, MD (1978).

TOLUENE

Toluol

$C_6H_5CH_3$

Skin

TLV, 100 ppm (\approx 375 mg/m³)

STEL, 150 ppm (\approx 560 mg/m³)

Toluene is a colorless liquid with a typical aromatic hydrocarbon odor. Its molecular weight and specific gravity are 92.13 and 0.866, respectively. The boiling point is 110.7° C and solidifies at -95° C. At 25° C, the vapor pressure is 28 mm Hg. The closed cup flash point is 40° F. It is insoluble in water, but miscible with most organic solvents.

Formerly derived solely from coal tar, toluene is now obtained chiefly from petroleum, and is present in gasoline and many petroleum solvents. It is used as a solvent in paints and coatings, for rubber, oils, resins, etc.; as a raw material for the manufacture of benzene and a host of other chemicals, including TNT, TDI, and ingredients of detergents, dyes and drugs.

Because of its wide industrial use and chemical similarity to benzene, the literature of industrial toxicology and industrial medicine, particularly the latter, record numerous investigations of the toxic effects of toluene. According to Patty⁽¹⁾ the concentrations of toluene and benzene required to cause prostration of mice are apparently 3000 ppm and 4700 ppm, respectively. Death from acute poisoning results from 10,000 ppm toluene compared with 14,000 ppm of benzene. Several incidents of workers being overcome by toluene vapor, usually in confined spaces, have been reported. Longley and co-workers⁽²⁾ describe such an event aboard ship where 26 men were overcome. There were no deaths or serious aftereffects. No irritation of eyes or respiratory passages was observed.

From the standpoint of chronic poisoning, toluene does not cause the severe injury to the bone marrow characteristic of benzene poisoning. Gerarde⁽³⁾ stated that the myelotoxicity of benzene was completely absent in toluene and other alkyl derivatives of benzene. Von Oettingen et al⁽⁴⁾ found that exposure of rats at 2500 to 5000 ppm of toluene caused a temporary decrease in the white-cell count, but no evidence of injury to blood-forming organs or liver. Greenburg and co-workers⁽⁵⁾ studied a group of painters exposed to toluene in concentrations ranging from 100 to 1100 ppm. Their findings included enlargement of the liver, macrocytosis, moderate decrease in erythrocyte count and absolute lymphocytosis, but no leukopenia.

Wilson⁽⁶⁾ found that among workers exposed at less than 200 ppm of toluene there were some complaints of headache, lassitude and nausea, but physical findings were essentially negative. At concentrations between 200 and 500 ppm impairment of coordination, momentary loss of memory and anorexia were also present. Between 500 and 1500 ppm palpitation, extreme weakness, pronounced loss

of coordination and impairment of reaction time were noted. The red cell count fell in many instances, and there were two cases of aplastic anemia, in which recovery followed intensive hospital treatment. A later comment by Wilson,⁽⁷⁾ however, suggests that he did not rule out the possibility that some of the above effects were due to a benzene impurity in the toluene used.

According to Fairhall,⁽⁸⁾ severe exposure to toluene may result in a pronounced drop in the red count and partial destruction of the blood-forming elements of the bone marrow. However, Gerarde⁽⁹⁾ stated that extensive animal studies clearly indicate that toluene is not a bone marrow poison. While there have been occasional reports of aplastic anemia attributed to toluene,⁽⁷⁾ in some instances the presence of benzene was not precluded, and there have been no "epidemics" of this disease among toluene workers comparable to those which have resulted from benzene. Powars⁽¹⁰⁾ reported six cases of aplastic anemia, one of them fatal, among glue sniffers. Although toluene was the solvent chiefly used, no analysis was given of the glue involved in the fatal case. Exposures in these cases are much greater than would normally arise from occupational use of toluene. Thus Knox and Nelson⁽¹¹⁾ described an instance of permanent encephalopathy involving a man who inhaled toluene regularly for over 14 years.

Von Oettingen and co-workers⁽⁴⁾ found that human subjects exposed at 200 ppm suffered slight but definite changes in muscular coordination. They concluded that such concentrations were unlikely to have any discernible untoward effects on health. Gerarde⁽⁹⁾ however, believed that von Oettingen's work did not justify the 200 ppm limit. Ogata et al⁽¹²⁾ found that experimental human subjects exposed at 200 ppm for seven hours showed prolongation of reaction time, decrease in pulse rate and in systolic blood pressure. They consider 200 ppm too high as the MAC. Takeuchi⁽¹³⁾ exposed rats at 200 ppm and higher concentrations of toluene for 32 weeks and then to benzene for 39 days. On the basis of differences found between the toluene-exposed animals and controls, e.g., changes in weight of adrenal glands, he suggested that the MAC of 200 ppm for toluene should be reconsidered.

Smyth et al reported an oral LD₅₀, administered to rats, to be 7.53 mL/kg.⁽¹⁴⁾

On the basis of the above data, a reduction in the TLV for toluene from 200 ppm to 100 ppm is recommended, with a STEL of 150 ppm.

Other recommendations: Cook (1945) 200 ppm; Smyth (1956) comments that this limit may permit early signs of narcosis; Elkins (1959) 200 ppm; ANSI (1967) 200 ppm; USSR (1967) 14 ppm; Czechoslovakia (1969) 50 ppm; West Germany (1974) 200 ppm; Sweden (1975) 100 ppm; East Germany (1973) 50 ppm; NIOSH (1973) 100 ppm.

References:

1. Patty, F.S.: *Industrial Hygiene & Toxicology*, 2nd ed., Vol. II, p. 1226, Interscience, NY (1963).
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TRICHLOROACETIC ACID

TCA

CCl_3COOH

TLV, 1 ppm ($\approx 5 \text{ mg/m}^3$)

TCA forms deliquescent crystals with a molecular weight of 163.40 and a specific gravity of 1.6298. It is a relatively strong acid, which melts at 57.5° C, boils at 197.5° C and is nonflammable. TCA is soluble in water, alcohol and ether.

It is used in medicine, pharmacy, as a reagent for albumin detection and in making herbicides.

Trichloroacetic acid was first placed on the Notice of Intended Change in 1978 at 1 mg/m^3 . This value had been carried for 1979 and transferred to the adopted list in 1980. This value was in error. The TLV 0.75 ppm ($\approx 5 \text{ mg/m}^3$), which appeared on page 476 of the 1978 Supplemental Documentation V, was the value initially given TCA, and was to have been rounded off to 1 ppm, by analogy with 2,2-dichloropropionic acid (TLV 1 ppm). The numeral one was then inadvertently placed in the mg/m^3 column in-

stead of the ppm column, and this error was not discovered until now. The correct adopted TLV is 1 ppm ($\approx 5 \text{ mg/m}^3$) and this correction will be made in the second printing of the 1980 TLV booklet. The following documentation reflects this value.

The oral LD_{50} has been reported as 3.3 g/kg for rats;^(1,2) for mice, 5.64 g/kg.⁽³⁾ By intraperitoneal administration, 500 mg/kg was fatal to mice.⁽³⁾

TCA is corrosive to the skin and eye, but not readily absorbed through the skin. Medical reports of acute exposure effects showed mild to moderate skin and eye burns.

A time-weighted TLV of 1 ppm is suggested, based largely on analogy to 2,2-dichloropropionic acid, and the above meager data.

Other recommendations: USSR (1976) 0.75 ppm.

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2. **Dow Chemical Company:** Communication to Committee (1977).
3. **NIOSH:** *Registry of Toxic Effects of Chemical Substances* (1977).

1,2,4-TRICHLOROBENZENE

$\text{C}_6\text{H}_3\text{Cl}_3$

CEILING LIMIT, 5 ppm ($\approx 40 \text{ mg/m}^3$)

A colorless, stable liquid at room temperature, with an odor similar to that of o-dichlorobenzene, 1,2,4-trichlorobenzene has a molecular weight of 181.46 and a specific gravity of 1.4634 at 25° C. It melts at 17° C, boils at 213° C and has a reported flash point of 224.6° F. It is combustible and soluble in most organic solvents, but insoluble in water.

It is used as a dielectric fluid, heat transfer medium, in lubricants, insecticides and organic synthesis.

A study of the acute and subacute inhalation toxicity of trichlorobenzene (92% the 1,2,4-isomer) by Treon⁽¹⁾ indicated that the target organs from non-lethal exposures of cats, dogs, rats, rabbits and guinea pigs included the liver, kidney, ganglion cells at all brain levels, and mucous membranes. Local irritation of the lungs and functional changes in respiration, e.g., dyspnea, were noted in animals later dying from inhalation exposure.

Brown *et al*⁽²⁾ reported 1,2,4-trichlorobenzene to have a single dose acute oral LD_{50} of 756 mg/kg for rats and 766 mg/kg for mice. The acute percutaneous LD_{50} for rats was 6139 mg/kg. Sublethal doses administered repeatedly to guinea pigs caused liver damage. Acute and short term (15 x 6 exposures, 70-200 ppm) inhalation studies failed to kill animals, and produced lethargy and retarded weight gain with no organ pathology.⁽³⁾ Cameron *et al*⁽⁴⁾ reported that the trichlorobenzenes are less toxic to rats than the mono- and dichlorobenzenes.

The aforementioned studies are short term ones and information needed to recommend an airborne concentra-

tion to which workers may be repeatedly exposed during a working lifetime without adverse effects is limited. Cutaneous exposure to 1,2,4-trichlorobenzene does not cause chloracne or acneform dermatitis but can cause dermal irritation which is probably attributable to its degreasing action.⁽⁵⁾ Industrial data report an odor threshold of approximately 3 ppm and minimal eye and throat irritation at 3-5 ppm in certain people.⁽⁶⁾ Twenty male rats, 4 rabbits and 2 male dogs were exposed at either 30 or 100 ppm 1,2,4-trichlorobenzene (98.4% purity, 1.4% 1,2,3-trichlorobenzene) 7 hours/day, 5 days/week for 30 exposures in 44 days. No adverse effects were detectable at 30 ppm with the exception of an elevation of urinary uroporphyrin and coproporphyrin in the rats only at 15 and 30 exposure days. No pathologic lesions could be attributed to the exposure in roughly 30 different specimens examined for each species.⁽⁶⁾ A second inhalation study was performed with 99.07% pure 1,2,4-trichlorobenzene 7 hours/day, 5 days/week for 26 consecutive weeks.⁽⁷⁾ Thirty rats, 16 rabbits, and 9 monkeys, all males, were exposed at zero, 25, 50 and 100 ppm. Pulmonary function and operant behavior in monkeys, ophthalmoscopic examination in rabbits and monkeys and body weight measurements, hematology and serum biochemical determinations in all species were conducted prior to and during the exposure period; no differences were noted among the four exposure groups. Microscopic changes were seen in the parenchymal cells of livers and kidneys from all groups of rats after 4 and 13 weeks of exposure to 1,2,4-TCB, but no exposure-related abnormalities were seen after 26 weeks of exposure in any of the three species under study.

The above data do not indicate a high systemic toxicity. The recommended ceiling limit of 5 ppm, based on the irritating properties of TCB, seems low in comparison with

done because of its decomposition in the soda-lime circuit into toxic and flammable dichloroacetylene, phosgene and carbon monoxide.

The sites of biological effects of trichloroethylene: 1) CNS (euphoria, analgesia, anesthesia); 2) Liver (necrosis, hepatomas); 3) Kidney (necrosis); 4) Lung (tachypnea); 5) Heart (arrhythmias); 6) Skin (irritation, vesication; paralysis of the fingers immersed in liquid trichloroethylene); 7) Bone marrow (myelotoxic anemia).

The knowledge of acute toxicity of trichloroethylene comes mainly from its use as an anesthetic.⁽¹⁾ Tachypnea and ventricular arrhythmias are equated with overdosage (inhaled concentrations greater than 15000 ppm).

Vernon and Ferguson⁽²⁾ found that a two-hour exposure of a volunteer to 1000 ppm of trichloroethylene resulted in adverse effects on visual perception and motor skill; but two-hour exposures at 300 ppm and 100 ppm produced no significant effect. In a later report, the same authors⁽³⁾ noted that low levels of alcohol in the blood (20-30 mg/100 mL) markedly augmented the effect of the two-hour exposures to trichloroethylene at concentrations of 300 and 1000 ppm.

Hepatic injury was observed in rats⁽⁴⁾ exposed for 2 hours to a trichloroethylene concentration of 10,000 ppm, when the rats were pre-treated with phenobarbital, Aroclor 1254, hexachlorobenzene, 3-methyl cholanthrene or pregnenolone-16- α -carbonitrile. Liver injuries are associated with extensive metabolism of trichloroethylene in the body.

Death in laboratory animals from acute exposure to trichloroethylene vapor also results from respiratory failure or cardiac arrest.^(5,6) Trichloroethylene is reported to have direct action on the bone marrow of rabbits, causing myelotoxic anemia.⁽⁷⁾ It caused residual brain damage in dehydrated rats⁽⁸⁾ exposed to 3000 ppm of trichloroethylene. Eight-hour exposure to any concentration higher than 3000 ppm might be fatal.⁽⁹⁾

Adams and associates⁽⁹⁾ found no adverse effects when monkeys were exposed repeatedly at 400 ppm, rats and rabbits at 200 ppm, and guinea pigs at 100 ppm. Adams *et al* concluded from their animal studies that exposure to 100 ppm is probably safe for humans.

Stoppa and McLaughlin⁽¹⁰⁾ exposed volunteers to 100 ppm of trichloroethylene and found no changes in various performance tests, but did note some changes at higher concentrations. Steward and associates⁽¹¹⁾ reported that volunteers exposed to 200 ppm of trichloroethylene for seven hours a day showed mild responses such as slight fatigue and sleepiness on the fifth day of exposure. There were no measurable objective responses. Also, Triebig *et al*⁽¹²⁾ exposed seven healthy volunteers to 100 ppm of trichloroethylene for five days observing no impairments of the examined person's mental or psychological capacities. On the other hand, Ertle *et al*,⁽¹³⁾ in a similar study, observed fatigue, lassitude and headache in his volunteers.

Several European authorities, reported symptoms in workers exposed to concentrations generally below 100 ppm. Ahlmark and Forssman⁽¹⁴⁾ estimated exposure to trichloroethylene by measuring the urinary excretion of trichloroacetic acid. They found the chief symptoms to be abnormal fatigue, irritability, headache, gastric disturbances and intolerance to alcohol. Ahlmark and Friberg⁽¹⁵⁾

tentatively suggested 30 ppm as a desirable limit for the time-weighted average occupational exposure.

Haas⁽¹⁶⁾ and Grandjean *et al*⁽¹⁷⁾ found a variety of nervous disturbances in a group of 50 workers exposed to trichloroethylene vapor at concentrations ranging from 10 to 335 ppm. These disturbances increased with the length of exposure (up to five years or more), and were distinctly more frequent when trichloroethylene concentrations exceeded 40 ppm.

Bardodej and Vyskocil⁽¹⁸⁾ also recommended a limit of about 40 ppm, finding signs and symptoms of chronic trichloroethylene poisoning including intolerance to alcohol, tremors, giddiness and anxiety at an exposure above 40 ppm.

Lilis and co-workers⁽¹⁹⁾ reported that workers exposed at concentrations averaging about 10 ppm (12% of the tests showed values about 40 ppm) complained of headache, dizziness and sleepiness.

Smyth and associates reported an oral LD₅₀ to be 4.92 mg/kg and, after four hours exposure, a lethal concentration to be 8000 ppm.⁽²⁰⁾ Rats were used in both instances.

Trichloroethylene was found neither embryotoxic nor teratogenic in Sprague-Dawley rats and Swiss Webster mice inhaling trichloroethylene for seven hours at a concentration of 300 ppm on days 6-15 of gestation.⁽²¹⁾

Trichloroethylene was found to be weakly mutagenic in the metabolizing *E. coli* mutagenic systems.⁽²²⁾

Recently trichloroethylene came under investigation as a possible carcinogen. The concern was initiated by a report from the National Cancer Institute⁽²³⁾ that hepatocellular carcinomas resulted from oral administration of trichloroethylene to mice. In this bioassay, male and female rats (Osborne-Mendel) and mice (B6C3F1) were exposed to trichloroethylene for 18 months with an observation period of 3-6 months following exposure. Rats were given doses at either 1000 mg/kg or 500 mg/kg, 5 times/week. Male mice were given 2400 or 1200 mg/kg and female mice 1800 mg/kg or 900 mg/kg doses 5 times/week. Hepatocellular carcinomas were not seen in the rats; 30 of the 98 (30.6%) mice given the low dose, and 41 of the 95 (43.2%) mice given the high dose developed hepatocellular carcinomas. Only 1 (2.5%) of the 40 control mice developed a carcinoma.

A cohort study on trichloroethylene exposure and cancer in man, conducted recently in Scandinavian countries⁽²⁴⁾ in 7,688 workers exposed to relatively small concentrations of trichloroethylene, did not reveal any excess cancer mortality. Half of the population under study was exposed to trichloroethylene for more than 10 years: 548 persons were exposed to trichloroethylene concentrations greater than 30 ppm, 3,095 persons to concentrations smaller than 30 ppm. The exposure was evaluated from urinary excretion of trichloroacetic acid, 100 mg/L being associated with an eight-hour exposure of 30 ppm of trichloroethylene, a time-weighted exposure.

A TLV of 50 ppm and 150 ppm as a STEL are recommended for trichloroethylene to provide workers with adequate protection against the toxic effect.

Other recommendations: ANSI (1967) 100 ppm, OSHA (1978) 25 ppm; Czechoslovakia (1969) 45 ppm, for brief exposures 225 ppm; Germany (1970) 50 ppm; Sweden 30 ppm; USSR (1967) 2 ppm.

In light of the above evidence that neither acute or chronic effects occur from repeated daily exposures after many years, and that irritation may be experienced at around 20 ppm, but not at 10 ppm, the recommended TLV for vinyl acetate is 10 ppm, with a STEL of 20 ppm.

Other recommendations: USSR MAC (1976) 3 ppm; NIOSH (1978) 4 ppm ceiling.

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VINYL BENZENE

See, STYRENE

VINYL BROMIDE

Bromoethylene



TLV, 5 ppm ($\approx 20 \text{ mg/m}^3$), Appendix A2 — Suspected Carcinogen

Vinyl bromide has a molecular weight of 106.96 and the liquid has a specific gravity of 1.4933 at 20° C. It has a melting point of -139.54 and a boiling point of 15.80 at 760 mm Hg. Insoluble in water, it is soluble in alcohol, ether, acetone, benzene or chloroform.

This substance has not been found suitable as an anesthetic, but is useful as a fire-retardant in plastics.

The oral LD₅₀ of the 50% solution in corn oil is 500 mg/kg in male rats.⁽¹⁾ Liquid vinyl bromide is slightly to moderately irritating to the eyes, but non-irritating to intact or abraded rabbit skin. Acute inhalation studies show that 100,000 ppm is lethal to rats in 15 minutes; 50,000 ppm renders rats unconscious in 25 minutes and is lethal after 7 hours of exposure. At 25,000 ppm, rats are anesthetized, but recover rapidly even after 7 hours of exposure. Slight to moderate kidney damage was seen in rats surviving exposure to 50,000; but no histopathological changes were seen in rats exposed 7 hours to 25,000 ppm.

A sub-acute inhalation study in rats exposed to 10,000 ppm for 7 hours per day, 5 days per week, revealed significantly depressed body weights after 15 days of exposure, but no compound-related gross or microscopic pathological changes after 20 exposure days.⁽²⁾

In a chronic inhalation study, in which groups of rats, rabbits and monkeys were exposed to 250 or 500 ppm for 6 hours/day, 5 days/week for 6 months, no significant changes were detected in any of the following parameters: growth rates, food consumption (rats and rabbits only), hematology, gross pathology, organ to body weight ratios and histopathology.⁽²⁾ Measurements of blood bromide showed that the levels increased with duration of exposure to all three species and were proportional to the concentration of vinyl bromide in the test atmosphere. Estimated equilibrium values for blood bromide in monkeys exposed to 250 and 500 ppm were well below those levels at which signs of bromism were evident.

Based on interim data obtained after 12 months of a lifetime inhalation study, there appear to be serious toxic effects in Charles River Sprague-Dawley rats exposed to 1250 or 250 ppm 6 hours/day, 5 days/week.⁽³⁾ The toxic effects include increased mortality, decreased body weight, angiosarcomas of the liver and carcinomas of the zymbal glands of the ears. These responses were dose related and did not occur in groups of male and female rats similarly exposed for 1 year to 50 ppm or 10 ppm.

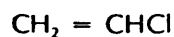
Based on these data a TLV of 5 ppm, the same as that for vinyl chloride, is recommended, as well as placement on the A2 listing as a suspected human carcinogen.

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VINYL CHLORIDE

Chloroethene



TLV, 5 ppm ($\approx 10 \text{ mg/m}^3$) — Appendix A1a — Recognized Carcinogen

A colorless, highly flammable gas with an ethereal odor, vinyl chloride has a molecular weight of 62.50. It boils at

-13.9° C and freezes at -159.7° C. Vinyl chloride is usually handled as a liquid under pressure, and containing a polymerization inhibitor (phenol). It is slightly soluble in water, but dissolved by alcohol and ether.

The chief use of vinyl chloride is as a raw material for the manufacture of polyvinyl chloride resins. It is also employed in organic syntheses.

Since vinyl chloride is a gas at room temperature and pressure, the common route of toxic exposure is by inhalation. As with many liquified gases, contact of the skin or

After leaving the working environment, a state of somnolence (45%) persists, with hypersomnia. Vinyl chloride acts on the skin and produces a sensation of formication and of heat.

2. After repeated exposure, a neurologic asthenia sets in which somnolence predominates.
3. After a variable period of time, dyspeptic disturbances are added to the neurologic manifestations; these are at first not characteristic; they are in the form of epigastric pains (16%), swelling, discomfort, feeling of heaviness in the right hypochondrium (7%) or the left (5%) with anorexia, particularly for fats. In 30.2% of the cases, congestive hepatomegaly appears, which may mimic toxic hepatitis without jaundice; some cases may become chronic. In 6% of the cases, the hepatomegaly is accompanied by splenomegaly. The proteinogram and the aldolases are the most sensitive tests and show changes similar to those of acute hepatitis: increase in α -globulins and of the β - and γ -globulins; and thymol test, Greenstedt's reaction and the zinc sulfate test are positive only in few of the cases.
4. After 3 years of exposure in 9% of the cases a syndrome typical of ulcer without radiologic changes becomes manifest.
5. In 6% of the cases the Raynaud syndrome has appeared, particularly among the young men. Plethysmography shows in half of the cases an inhibition of the vasomotor centers.
6. In addition, allergic dermatitis in 4.4% of the cases, and scleroderma in 3.6%, has been observed.
7. The clinical and laboratory findings are of great importance in occupational pathology because in numerous cases diseases appear in man that cannot be reproduced in the animal (Raynaud's syndrome and scleroderma).

The sudden and frequent appearance of these manifestations in the PVC division of several plants, and in certain divisions in normal individuals who are still relatively young, and their disappearance in the majority of the cases after the institution of protective measures and change of work, have shown us decisively that vinyl chloride and the vinyl monomers have played a part in the production of these manifestations. (End of author's summary).

In 1967, reports appeared in the literature describing a condition known as acroosteolysis in workmen engaged in polymerization of vinyl chloride to polyvinyl chloride. Harris and Adams⁽¹³⁾ reported on two cases in Europe. Wilson et al⁽¹⁴⁾ reported on 37 cases in the B. F. Goodrich Company. Juhe et al⁽¹⁵⁾ described a syndrome consisting of (arranged in decreasing order of occurrence) thrombopenia, splenomegaly, liver damage, obstruction of ventilation, circulatory obstruction, and skin and bone alteration.

As a result of this problem, the University of Michigan in 1967 was retained by the Manufacturing Chemists Association to investigate acroosteolysis in sponsoring American companies. The results of a large scale epidemiological study of workers then currently employed in vinyl chloride and polyvinyl chloride production were reported in three publications by this group Dinman et al,⁽¹⁶⁾ Cook et al⁽¹⁷⁾ and Dodson et al.⁽¹⁸⁾

Dinman et al⁽¹⁶⁾ summarized the study as follows:

"An epidemiological study was performed covering 5,011 employees with 21,510 man-years experience in various phases of vinyl chloride (VC) and polyvinyl chloride (PVC) manufacturing in 32 plants throughout the United States and Canada. The total number of definitive cases of acroosteolysis (AOL) was 25; 16 other individuals were under suspicion. This condition is clearly associated with the hand cleaning of polymerizers. Workers engaged in other phases of VC or PVC manufacturing do not appear to be at risk of developing AOL. The importance of Raynaud's phenomenon as a concomitant of AOL is emphasized. Several statistical approaches for rapid medical survey are suggested. Acroosteolysis appears to be a systemic rather than local disease. Presently, neither the etiological agent nor its portal of entry is known."

Cook et al⁽¹⁷⁾ describes the polyvinyl chloride production process in considerable detail. They concluded that although no etiological agent could be identified, "There appeared to be a correlation between the extent of degassing prior to entry into the reactor" and the incidence of acroosteolysis.

Mutchler and Kramer⁽¹⁹⁾ presented a paper at the 1968 Gordon Research Conference which was subsequently published (1972), which reported on *The Correlation of Clinical and Environmental Measurements for Workers Exposed to Vinyl Chloride*. The authors drew the following conclusion:

"Our findings suggest that repeated exposure to vinyl chloride at TWA levels of 300 ppm or above for a working lifetime together with a very low level of vinylidene chloride may result in slight changes in certain physiologic and clinical laboratory parameters. The possibility of some impairment in liver function tests must be considered, even though no overt clinical disease was evident in any of the individuals studied. We shall continue our study, but suggest that similar studies to help clarify the effects of this material be performed for other worker populations exposed to vinyl chloride alone."

P. L. Viola, in an attempt to produce acroosteolysis in animals, exposed rats 4 hours per day, 5 days per week to 30,000 ppm (3%) vinyl chloride vapor. In his first report on the results of 12 months exposure, he described metaplastic changes in the bones which he considered similar to the human disease acroosteolysis. He made no mention of having observed cancer in these animals until the Tenth International Cancer Congress in May 1970. In the abstracts of this meeting, and subsequently in May 1971, Viola, Bigotti and Caputo⁽²¹⁾ reported tumors of the skin, lungs and bones occurring first after 10 months of exposure. The authors summarized this work as follows:

"Rats (Ar/IRE Wistar strain) exposed for 12 months to vapors of vinyl chloride developed tumors of the skin, lungs, and bones. The cutaneous tumors, which always appeared in the area in which submaxillary and parotid glands are located, have been histologically recognized as epidermoid carcinomas, papillomas, and mucoepidermoid carcinomas. The morphological characteristics of lung tumors, which

Recent papers have included a report of 4 cases of respiratory cancer among vinyl chloride workers, but no dose-response relationship.⁽³¹⁾

On the other hand, Fox and Collier,⁽³²⁾ in a study of 7000 men exposed to vinyl chloride in PVC manufacture between 1940 and 1974, found no evidence of cancers due to vinyl chloride at sites other than the liver. There are four liver cancers, two of them angiosarcomas.

Delorme and Theriault⁽³³⁾ described 10 cases of liver angiosarcoma among workers in vinyl chloride polymerizing plant in Quebec, which were accompanied by fibrosis of the liver. Details of 64 cases were presented by Sputas and Kaminski.⁽³⁴⁾

Mutufugi, in Japan, noted that in contrast to western countries, in which 70 angiosarcomas cases (associated with vinyl chloride exposure) had been reported, no cancer, but many poisoning cases, have been reported in the USSR.⁽³⁵⁾

Based on the above data, an A1a classification as a confirmed carcinogen is given vinyl chloride and a TLV of 5 ppm as a time-weighted average is suggested. If this value is not exceeded, there should be no increase in the incidence of cancer, especially angiosarcoma of the liver.

Limits adopted in other countries, subsequent to the surfacing of vinyl chloride exposure associated cancers, as are follows, according to a 1977 summary: Australia (1973) 25 ppm; Finland (1975), Holland (1973), Poland (1976), Switzerland (1976) and USSR (1977) about 10 ppm; Italy (1975) 5 ppm; Japan (1975) and Sweden (1978) 1 ppm.

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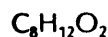
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VINYL CYANIDE

See, ACRYLONITRILE

VINYLCYCLOHEXENE DIOXIDE

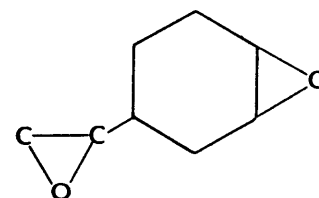
Vinylhexane dioxide



Skin

TLV, 10 ppm ($\approx 60 \text{ mg/m}^3$), Appendix A2 — Suspected Carcinogen

A colorless liquid which has a specific gravity of 1.0986 at 20° C, vinylcyclohexene dioxide's molecular weight is 140.18. Its freezing point is -108.9° C and boiling point is



228° C. The open cup flash point is 230° F and the viscosity is 7.77 centipoise at 20° C. The vapor pressure is 0.1 mm Hg at 20° C and is very soluble in water.

Vinylcyclohexene dioxide has been used by the plastic industry since the 1950's in the formation of polymers and other types of organic syntheses.⁽¹²⁾

XYLENE



o-, *m*-, *p*-isomers

TLV, 100 ppm (≈ 435 mg/m³)

STEL, 150 ppm (≈ 655 mg/m³)

Xylene is a clear, flammable liquid with an aromatic hydrocarbon odor and a molecular weight of 106.16. Commercial xylene is a mixture of three isomers, ortho, meta and para, with the meta form usually the principal component. According to Gerarde,⁽¹⁾ 6 to 15% of ethyl benzene may also be present. The physiochemical properties of the three isomers, meta, ortho, para, respectively, are: specific gravity, 0.8684, 0.88801 and 0.86104; boiling point, 138.8, 144 and 138.5° C; melting point, -47.4, -25 and -13 to -14° C. The vapor pressure at 25° C is between 7 and 9 mm Hg. The boiling ranges and flash points of the commercial product depends on its grade; the 10% grade boils between 135 and 145° C; closed cup flash points are from 81 to over 100° F. Xylene is insoluble in water, but miscible with absolute alcohol, ether and other organic solvents.

Xylene is present in gasoline and many petroleum solvents. It is used extensively as a solvent in paints and other coatings, especially the alkyl resin type, and in rubber cements. Meta-xylene is an intermediate in the preparation of isophthalic acid; ortho-xylene in the manufacture of phthalic anhydride; para-xylene in the synthesis of terephthalic acid. All isomers are used in making drugs, dyes and insecticides.

Fairhall⁽²⁾ considered the effects of xylene similar to those of toluene, but Gerarde^(1,3) stated that the acute toxicity of the xylenes was higher.

Fabre and Truhaut⁽⁴⁾ exposed rats and rabbits to a mixture of xylene isomers at a concentration of about 690 ppm for eight hours a day, six days a week. After 130 days no significant deviations from normal in the peripheral blood were found. A decrease in red and white cell counts and an increase in the platelet count in the blood of rabbits followed similar exposures at 1150 ppm for 55 days. Reversible lesions in the cornea of cats exposed to xylene were observed.

Gerarde⁽¹⁾ listed headache, fatigue, lassitude, irritability and gastrointestinal disturbances such as nausea, anorexia and flatulence as the most frequent symptoms among workers exposed to xylene. A report which suggested that xylene might affect the heart and vascular system was cited.

Browning⁽⁵⁾ also recorded reports of gastrointestinal as well as neurological disturbances, and injury to heart, liver, kidneys and the nervous system among workers with xylene exposure. In addition, she noted a number of reports of blood dyscrasias, some of them fatal, associated with exposure to xylene. De Oliveira⁽⁶⁾ described the death from aplastic anemia of a lithographer who used xylene for several years; and Goldie⁽⁷⁾ reported a patient who had an

apparent epileptiform seizure following relatively brief exposure to xylene vapor.

Gerarde,⁽¹⁾ however, considered that industrial experience confirmed the animal experimentation evidence that xylene is not a myelotoxicant. Goldwater⁽⁸⁾ was of the opinion that xylene was probably less toxic than toluene to the bone marrow. In most of the cases of blood disease associated with xylene, the presence of benzene as an impurity was not ruled out.

Nelson and associates⁽⁹⁾ found 200 ppm of xylene definitely irritating to the eyes, nose and throat of experimental human subjects. Greenburg and Moskowitz⁽¹⁰⁾ suggested a maximum allowable concentration of 200 ppm. Cook,⁽¹¹⁾ Smyth,⁽¹²⁾ Elkins⁽¹³⁾ and Gerarde⁽²⁾ all considered this value too high, and Gerarde suggested 100 ppm as a more acceptable limit.

The NIOSH criteria document on xylene, published in 1975,⁽¹⁴⁾ refers to a report by Morley *et al*⁽¹⁵⁾ in which renal impairment and some evidence of disturbance of liver function were noted in three workers who were overcome by a gross overexposure to xylene (estimated concentration, 10,000 ppm): one worker died, the others suffered from amnesia and did recover, slowly however. A paper by Matthaus describes corneal changes in furniture polishers exposed to xylene in unknown concentrations.⁽¹⁶⁾

In a study of various hydrocarbon solvents, Carpenter *et al*⁽¹⁷⁾ found the 4-hour LC₅₀ for rats to be 6700 ppm. The *no-ill-effect* concentration for rats and dogs, following 65 days (6 hours/day, 5 days/week) was 800 ppm. Sensory response experiments with human subjects indicated a hygienic standard of around 200 ppm.

The TLV of 100 ppm, first adopted in 1967, is retained with a STEL of 150 ppm. It is believed that irritant effects will be minimal, and that no significant degree of narcosis or chronic injuries will result from continued occupational exposure at that level.

NIOSH⁽¹⁴⁾ also recommended a workplace environmental standard of 100 ppm, as a TWA, with a ten minute ceiling of 200 ppm.

Other recommendations: ANSI (1970) 100 ppm; West Germany (1974) 200 ppm; Sweden (1975) 100 ppm; Czechoslovakia (1969) and East Germany (1973) 45 ppm; USSR (1972) 11 ppm.

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